# THE AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS

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# General Sessions

# The American Society of Sugar Beet Technologists[1]

H. E. Brewbaker[2]

In trying to decide what I should discuss with you I found it difficult to choose between two desires. I would have enjoyed bringing to you a story of some of the modern advances in plant breeding—how the plant breeder has worked hand in hand with the plant pathologist and other plant scientists to bring into a hungry world varieties of wheat, corn, oats, and other crops resistant to the ravages of diseases that used to peril these crops, and how for our own sugar beet crop there have been similar amazing advances. But, instead, I have chosen to discuss our own American Society of Sugar Beet Technologists, since this was an opportunity for me to bring together something of the early developments which led to the organization of this Society, along with its present status and future possibilities.

Our organization is unique, in that it is the only technical society of its kind in this country devoted to one crop. There was no hesitation or extensive deliberation by the organizers about the need for such an organization, nor did there seem to be any apparent doubt about the possibility of its success. This, the fifth general meeting of the Society encourages one to think that it may continue to serve indefinitely as a permanent and essential medium for interchange of ideas and an outlet for release of experimental results to the public.

This Society was officially created at Salt Lake City on January 13, 1938, when the first constitution and by-laws were adopted. Preliminary to this, however, sugar beet people had been invited to Fort Collins, Colorado, each year for three years, beginning in 1935, to take part in a so-called "Sugar Beet Round Table." Particular credit is due T. G. Stewart, then extension agronomist for the Colorado State College of Agriculture, for taking the initiative in calling the first meeting of the Round Table in 1935, and for taking an active part in all three sessions. Acknowledgment is also due C. V. Maddux for encouragement and active participation in organizing and conducting the Round Table meetings.

Action was taken at the Second Annual Round Table in 1936 to invite sugar beet people from California to the 1937 meeting, at which time actually most of the sugar beet areas and research institutions interested in beets in the United States and Canada were represented. At the closing session, January 5, 1937, W. W. Robbins in a keynote address put added enthusiasm into the idea of a national society. Prompt action followed to create The American Society of Sugar Beet Technologists.

[1]Presidential address delivered to the 5th general meeting of the American Society of Sugar Beet Technologists, San Francisco, California, Jan. 12, 1948.

[2]Director, Longmont Experiment Station, The Great Western Sugar Company.

A. W. Skuderna, elected as its first president, drew up the first draft of the constitution and by-laws. Under his inspiring administration formal development took place, culminating in complete organization at the first general session at Salt Lake City.

Succeeding general meetings of the Society included the 1940 session at Denver with N. R. McCreery, president; 1942 at Salt Lake City with J. Earl Coke, president; and 1946 at Denver with Wilfred Y. Cannon, president. Due to war-time restrictions the 1944 meeting was not held.

This Society could not have been developed in so few years to such stature and dignity, as you will observe at this meeting, were it not for the whole-hearted cooperation of many people, all of whom were scientists either in their own right or in their personal interest. I would like to mention those men who have contributed so much to this development, but the list would be unduly lengthy and I can merely suggest that you take a few minutes sometime to go back over the Proceedings to see who they are.

The Proceedings of this Society have been preserved. For the first two meetings they were mimeographed, largely because of lack of funds to do otherwise. For the last two meetings the cost of printed Proceedings was underwritten by the United States Beet Sugar Association, and these constitute published volumes of which the Society and the industry can justly be proud. Because of limited editions, these Proceedings might well be expected to become of considerable historical value.

### Objectives of the Society

The purpose of the original Round Table was "to direct attention to improved methods of sugar beet culture and to develop more complete understanding regarding research and field experience between beet sugar companies, beet growers, and State and Federal workers." Representatives of both the growers and processors were invited to attend the meetings, it being held by the organizers that sugar beet research was of mutual concern to both groups and that research might serve to bring the entire industry more closely together. Actually, support from the processor was enthusiastic but only nominal from the growers' representatives. As one of those who took an active part in this enterprise the lack of support from the growers' group was a source of some disappointment, for by early experience and training my interest has largely centered around the farmer and his problems. The fact that we had to some extent failed to enlist wide and enthusiastic interest of growers no doubt entered into the planning for the national organization with its objective "to foster all phases of sugar beet and beet sugar research, and to act as a clearing house for the exchange of ideas resulting from such work."

I think it is safe to say that the results of much, perhaps most, of the research which will be reported at these meetings is of primary concern to the grower. His qualified representatives should be taking as active

a part in these meetings as either the processors or other industrial interests. Is it not reasonable to suppose that the grower should also contribute extensively to the support of research that makes possible improvements in methods of growing sugar beets and in the varieties themselves? I believe this Society can contribute a real service to the sugar beet industry by encouraging more interest and participation in its activities from the grower side of this great partnership of beet growing and processing.

This Society was developed on a strictly technical basis, and on this basis it has enjoyed a prosperous development and recognition by the industry which it serves, as well as by a scientific audience throughout the world. The Proceedings have served to place before the scientific world a compendium of recent advances in sugar beet research. From the standpoint of the scientist this constitutes a favorable outlet for strictly scientific publication, for it not only reaches the sugar beet audience but is also available to all scientists and administrators in other fields of science. This is an important feature which cannot be disregarded. In order to continue to enlist the support of our scientists, particularly those in State and Federal institutions, quality of the papers accepted and the standard of excellence adhered to in publication of the Proceedings or other official organs of the Society must be kept on a plane that will be both highly desirable and entirely legitimate as an outlet for their contributions, for without such contributions the Society itself would fail in its objectives.

Now, I fully realize that the two briefs just expressed, first for more grower participation in the activities of this Society, and second, for a continued and improved high scientific tone in our meetings and publications, may seem incompatible. Personally, I do not think so. I know many growers who are well qualified to read scientific literature, and furthermore, many of our best scientists today are specializing in writing or reporting so that they can be completely understood by the non-technical public.

In a plea for even better scientific writing a scientist of national reputation, A. J. Riker, plant pathologist, University of Wisconsin (4)[2], wrote recently, "Among the diseases of manuscripts, a diarrhea of words is perhaps the most common." To prepare a scientific report in a comprehensive manner, yet done clearly and simply so that one can always be understood, is an art worthy of real effort on the part of the scientist. It is an essential part of research and the manner in which it is done not only reflects upon the individual but upon the organization of which he is a part and the Society to which it is reported or the publication which accepts it. For this reason some special effort was made this year by the program chairmen and the editorial committee to improve the general level of the manuscripts prepared for this meeting.

There are, of course, fundamental phases in science which can only be treated in a manner to be understood mainly by fellow scientists, and

[2]Numbers in parentheses refer to literature cited.

such may be set off from those less technical as sectional programs at our Society meetings for the principal concern of scientists. Everything possible should be done to encourage such programs at our meetings, for out of these come the applications to our pressing problems.

### Need for Intensive Research

I picked up recently the following quotation from *Arrowsmith*, by Sinclair Lewis:

> "God give me unclouded eyes and freedom from haste. God give me a quiet and relentless anger against all pretense and all pretentious work and all work left slack and unfinished. God give me a restlessness whereby I may neither sleep nor accept praise till my observed results equal my calculated results or in pious glee I discover and assault my error."

Sometimes I think even the scientist takes entirely too much for granted. There is real danger of becoming provincial in our thinking. We need to spend time visiting with scientists in other fields, attending national meetings other than our own, and studying methods and results with other crops. In this, I speak particularly for those of us associated with research in an industrial organization, for we are more likely to be somewhat isolated from research institutions. This Society established a worthy precedent at its first meeting by inviting scientists in unrelated fields as guests of the Society to address the meeting. This practice is a valuable one which should be continued.

The orthodox, the accepted thing, all too often proves to be faulty when exposed to critical tests. Someone has aptly said, "There is nothing so perishable as an established product or idea." For example, probably most of you have heard growers, and sometimes others, remark that a reddish color developing quickly on a scarred beet means that it is "ripe," or has high sugar. We have checked sugars from hundreds of mother beets and have failed to find any correlation between this color and sugar content. The scientist needs imagination and some daring in designing experimental work, for the accepted may often be challenged with surprising results.

We have witnessed in recent years tremendous advances in the application of good scientific principles to the sugar beet crop. The development of a highly successful domestic seed industry presented the challenge of new varieties and this has been met with considerable success by our plant breeders and plant pathologists. Segmented seed resulted in a very important saving of labor. Cultural practice has been improved, and with approximately 17 percent of the 1947 beet acreage being harvested by machines, it is obvious that material progress has been made in mechanizing beet production. Beet by-products are appreciated more for their feeding value than ever before, this being particularly true now when grain shortages are severe as a result of world-wide demand for these products. Some new chemical by-products from the processing end are indicative of real

progress toward using "everything but the squeal," as they say in the hog-packing industry.

New developments and new information often serve to open up new opportunities. May I cite a few examples. One of the rather exciting possibilities coming out of atomic research is radioactive phosphorus which can be traced from the soil through the plant and animal, and it now becomes possible to determine accurately the phosphate-fixing power of our soils and the efficiency of the various methods of phosphate application. A host of new chemicals offer undreamed of possibilities of weed, insect, rodent, and disease control. New beet characters such as single-germ seed, a short, round root of concern to the engineer moving toward complete mechanization of the crop, and male sterility which becomes invaluable in a breeding program, are definitely in the picture of sugar beet improvement. To obtain the answers to these new problems, intensive research, additional highly trained personnel and resources will be needed.

In an address entitled "Industry, Science and the Public," Edward Pendray, assistant to the president of Westinghouse, made the following very pertinent remark, "No major industrial organization can long remain in business without research." To show the tremendous development of research as applied to industry the following facts[3] are of interest:

In 1920 297 industrial companies employed 7,400 research men

In 1927 1,000 industrial companies employed 19,000 research men

In 1940 2,350 industrial companies employed 70,000 research men

In 1945 the Du Pont Company (2) alone employed 3,500 men and women in their research department. In that company, research is considered as a major activity, research activities do not follow a "profit and loss" curve, highly trained personnel are employed, and fundamental research is recognized as "one of the most valuable phases of their research work."

While much has been accomplished by research in various phases of the sugar beet industry, I think we will all agree that the surface has only been scratched, and the need for further intensive research has never been recognized as it is now. In this connection in a keynote address to the 1947 Eastern Regional Meeting of this Society, Geoffrey S. Childs made a remark of particular significance to us: "It is through research that we may hope for strength and growth in our work," and of the American Society of Sugar Beet Technologists he said, "This has proved a boon to stimulating interest in research work."

### Cooperative Trends in Research

A Christmas card which came to my desk only recently may have been designed specifically with this Society in mind. At any rate, with two hands clasped together it appeared symbolic of what this Society stands for, and what I want to discuss with you for a few minutes; namely, cooperation and coordination in research.

[3]Reported by Mellon Institute.

The Farmers & Manufacturers Beet Sugar Association deserves credit for facilitating cooperative efforts between growers and processors as early as 1934, when it was organized. This Association has continued to serve the eastern segment of the sugar beet industry in an effective way since that time.

Various phases of fundamental research can best be carried on in the United States Department of Agriculture and the state universities. Industry is making an increasing demand upon the facilities of these institutions for trained personnel and for various phases of industrial research. There is some danger that for purely economic reasons or a desire to cooperate and to provide the answers to such requests that "these institutions may fail to keep in mind that the training of students and the conduct of basic research is their primary responsibility" (1).

Cooperation between industry and Federal or State research agencies can, however, be mutually productive. Many problems have been approached cooperatively by the Sugar Plant Office of the United States Department of Agriculture and industrial research agencies. There is no better example of cooperation between fundamental research and industry than the sugar beet machinery project at the University of California, which was administered so ably for a 16-year period under the supervision of H. B. Walker, a resume of which he is to give at these meetings.

At the third meeting of the Sugar Beet Round Table at Fort Collins, Colorado in 1937, Eubanks Carsner in a keynote address spoke on the "Value of Coordinated Research." His address was an informal one, and unfortunately, was not recorded in the mimeographed Proceedings of that meeting.

Some progress was made in this connection at the 1942 meetings when a Research Coordinating Committee appointed by President Earl Coke made rather specific recommendations for an active program of coordination of the efforts of various research agencies with the ultimate objective of bringing about a more comprehensive approach to the unending problems of concern to the sugar beet industry.

Cooperation in sugar research was effectively implemented through the organization of the Sugar Research Foundation, Inc., June 10, 1943, by the producers and processors of beet and cane sugar in the United States, Puerto Rico, Cuba, Canada, and the Dominican Republic. Grants-in-aid by this Foundation of half a million dollars are supporting fifty research projects on various phases of sugar. These studies cover a wide range of subjects: sugar in human metabolism, frozen fruit products, levulose extraction methods, beet by-products, dietary control of dental caries, utilization of sucrose by plants—to mention only a few. Research institutions throughout this country and Canada are cooperating. The fundamental basis on which the Sugar Research Foundation operates was aptly stated by its president, Ernest W. Greene: "Science is most fruitful when it is cooper-

ative—when interests, talents, and ideas are pooled and made easily available and when projects are coordinated to the major aims."

Of more direct concern to many of us is The Beet Sugar Development Foundation, which was created July 1945 by the United States Beet Sugar Association with the primary immediate objective of facilitating the mechanization of sugar beet growing. Of this very significant development the immediate past president of this Society, Wilfred Y. Cannon, had this to say in his presidential address: "Had it not been for the American Society of Sugar Beet Technologists, which brought industry and scientists close together, this kind of cooperative effort would not have been achieved."

In any event, the organization and encouragement of cooperative efforts in sugar beet research which has characterized the activities of The Beet Sugar Development Foundation during the short span of its existence is prophetic of a new era for the sugar beet industry in this country. For the limited base of its immediate objectives this Foundation has succeeded magnificently in carrying out the ideas of the research coordinating committee of this Society.

Wide-scale fertilizer tests constitute an excellent opportunity for cooperative relationships with the grower. The Utah-Idaho Sugar Company conducted such tests in cooperation with growers for 2 years with valuable results. In 1946, 50 such tests were conducted, the data being reported to the 1947 regional meeting of this Society. A similar wide-scale study was conducted in 1947 in a 4-state cooperation between the State Agricultural Experiment Stations of Colorado, Nebraska, Wyoming, and Montana, 75 cooperating growers, and The Great Western Sugar Company.

I mention these various developments merely as evidence of a growing spirit of cooperation in research on the sugar beet crop. They represent some of the more important developments during recent years which should be encouraging to everyone interested in the sugar beet industry. Scientific research has made great strides in connection with each of these developments.

In other parts of the World, however, biological research has not fared so well. It is not for any reason of boasting or particular gratification that we take note of the situation in our wartime ally, Russia, but because we have new members in this Society who found it necessary to give up their native country, Russia, for the freedom of scientific thought in this country. Dr. and Mrs. V. F. Savitsky, eminent scientists in their own right, have only recently arrived at Salt Lake City where they have come to serve the sugar beet interests and science in general in this country in their fields of genetics and cytology. The story back of their exodus from their homeland is one with which every one of us should become fully acquainted. It is a dramatic story of a world-recognized development in genetics and plant breeding which was reduced to a superficial shell under the relentless attacks of a suspicious Soviet dictatorship encouraged by a

false scientific premise (3). This story is a bit sobering as one becomes fully acquainted with all its implications. May we take a solemn resolve that scientific research here may always remain free and unfettered from dictatorial direction. Let us extend the right hand of scientific fellowship to these friends who have so recently come from Russia to join us at a time when we are more than ever aware of the advantages of research.

Finally, in this brief resume of the development and present status of our Society I think we might pause to remind ourselves that ours is a youthful industry; that whereas sugar was first produced from sugar beets just 201 years ago by Andreas Marggraf, the industry in the United States dates back less than 70 years to the first successful factory operation. Our Society has appropriately paid tribute to some of the "Old Timers." We are in a most exciting period of development, one which is a challenge to all of us who are active in research. As we look back on this occasion and this period a few years hence, I am sure we will all feel some real satisfaction in having had a part in making the sugar beet crop an indispensable part of agriculture in America.

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# Administration of the Sugar Act of 1948

JAMES H. MARSHALL[1]

I KNOW YOU will recognize that the administrative operations under the Sugar Act of 1948 are so comprehensive that it will not be possible to discuss in any detail the problems involved in the administration of each of the major sections of the Act. Therefore, it will be necessary to select a few provisions of the Act which are of most interest currently and discuss them briefly. I know that some of you have questions regarding numerous specific provisions of the Act and how the administration of such provisions may affect your particular circumstances. I expect to be here during the remainder of this week and during such period I shall be glad to discuss with any of you any such questions you may have. Because of the nature of the interests of this group of technologists I want to go beyond my assigned topic to discuss briefly the research program of the Department of Agriculture under The Research and Marketing Act as it relates to sugar.

The Sugar Act of 1948 is in the most practical sense an extension of the Sugar Act of 1937, as amended, but it is an extension which takes recognition of numerous changes which have taken place in the sugar industry during the past few years. The general objectives of the 1948 Act, as stated in its title, are identical with the objectives stated in the title of the 1947 Act. The methods of obtaining the objectives have been modified to some extent in the new Act.

Among the changes in methods contained in the new Act are the provisions of its Section 201, which deals with the factors to be considered by the Secretary of Agriculture in his determination of the amount of sugar needed each year to meet the requirements of consumers in the continental United States. The guiding principle of this determination is that it "shall be made so as to protect the welfare of consumers and of those engaged in the domestic sugar industry by providing such supply of sugar as will be consumed at prices which will not be excessive to consumers and which will fairly and equitably maintain the welfare of the domestic sugar industry . . ."

A great deal of comment has been occasioned by the inclusion in this section of the Act of the ratio of price to cost of living as a factor to be considered in determining consumption requirements. An occasional inference is heard to the effect that the price of sugar which the Secretary must aim for can automatically be calculated from the cost-of-living index. This inference, of course, is wrong. If any such absolute relationship between the cost-of-living index and the price of sugar had been intended there would have been no point in including the other bases and standards which are a part of Section 201 of the Act. The cost-of-living factor is

[1]Director, Sugar Branch, United States Department of Agriculture.

not interpreted by the Department of Agriculture as a controlling or overriding factor in determining a price for sugar which must prevail during 1948 or any other year. This ratio of price to cost of living is simply one factor among several others which must be taken into account in determining the level-of-consumption requirements. It was our understanding at the time the bill was under consideration in the Congress, and it still is our understanding, that this interpretation is generally accepted.

In accordance with the law, this factor must be taken into account. In announcing the consumption estimate for 1948, the Department stated that after determining the base quantity of sugar, the quantity consumed during the 12-month period ending October 31, 1947, and after making allowances for deficiencies in inventories and for changes in population and demand conditions, no additional allowance was required at this time with respect to the relationship between the price of sugar and the cost of living. This did *not* mean the cost-of-living factor had not been taken into consideration. It merely meant that after making allowances for the other factors it was not considered necessary at this time to make any further allowance for the cost-of-living factor in order to achieve the price objective which the Department felt should be achieved by its estimate.

Already we have had complaints that the initial consumption estimate is too high and will result in prices too low to fairly and equitably maintain and protect the welfare of the domestic sugar industry. It seems to me that it is a little early for this complaint to be backed with vigor. We make no claim of infallibility in our capacity to make an estimate at this time which will prove to be a correct and final estimate for the year. We recognize that under current circumstances, representing very significantly changed economic conditions since the time of the pre-war consumption estimates, many of the old guide posts are of limited value until they can be checked and adjusted by experience under the new conditions of national income and purchasing power existing today. Obviously, the current estimate indicates our best judgment as to the quantity of sugar which can be marketed at prices which we feel will meet the standards of the Act. If our judgment is proved to be wrong, as it very well might be, adjustments will be necessary. Under the current high levels of purchasing power it seems the United States might easily consume 7,800,000 short tons of sugar at price levels not significantly different from those which recently have prevailed at the wholesale (primary distributor) level as long as other economic conditions do not change significantly. However, the mere fact that what may appear to be a liberal estimate has been made in the beginning in order to assure consumers that an adequate supply of sugar will be made available should not be used as a means of pushing down prices early in the year to a point below that which should be expected as an average for the year on the assumption that the initial consumption estimate will prevail throughout the year. It would be a mistake to use the original estimate for such purposes because if it were used in such manner the

only result would be a necessary reduction in the estimate. This would not be to the best interest of consumers.

It should be recognized that the quota system, which is based on the consumption estimate, is limited in the degree to which it determines a price level for sugar. It has been generally assumed that a low estimate of consumption automatically insures a high price level and a high estimate of consumption will produce a low price. While the tendencies will be in these directions, the result will not always be as indicated. For example, in the years 1936 and 1937, when the highest sugar quotas of the 1934-38 period were established, the price of sugar, duty paid, averaged higher than in the years of low estimates. A number of factors are involved. Of special importance is the quantity of sugar available behind the quota wall awaiting disposition. Based on the most recent estimate of this year's Cuban crop, there will be a large quantity of sugar available above requirements which can be backed by the necessary dollars. The outlook for the disposition of this large volume of sugar will no doubt have a very significant influence on our sugar market in the United States until final decisions are made regarding the quantities of sugar which can be sold by Cuba to foreign countries under the various foreign relief and aid programs.

The 1948 Act revises the method of establishing quotas after determination of the consumption estimate. I believe most of you are familiar with the method by which the Act allots fixed quotas to each of the domestic areas and the Republic of the Philippines and allots the difference between such fixed quotas and the total consumption estimate to Cuba and foreign countries other than Cuba and the Philippines. The beet sugar industry is alloted a fixed quota of 1,800,000 short tons raw value, which cannot be reduced except in the very unlikely event of a drastically low level of consumption. Should consumption fall to an extremely low level, some reduction in the beet quota would be required—as would be the case with all other domestic area quotas—to assure Cuba a minimum quota equivalent to 28.6 percent of the total consumption estimate. This is the percentage of the total which Cuba had under the 1937 Act. It is possible for the beet area quota to exceed the 1,800,000 short tons figure through re-allocation of any deficits which might occur in other domestic areas or in Cuba. For example, it has already been announced that a deficit of 152,000 short tons is anticipated in the Hawaiian quota for 1948 and as a result of this the beet area quota already has been adjusted upward by 47,738 short tons for 1948.

The 1948 Act, in addition to alloting a considerably larger quota to the beet sugar industry than it received under the 1937 Act, makes it possible to plan operations on the basis of a definite and fixed minimum quantity which may be produced and marketed over a period of 5 years.

Since the enactment of the Sugar Act of 1948 I already have heard occasional comments by persons in the beet sugar industry that the fixed quota for the industry is too small, citing the fact that the production this

year will be approximately at the quota level. I believe it is generally recognized that no area received as large a quota as it wanted or felt it was entitled to. The important fact is that a basis was found on which the several areas could agree, after each area gave up a part of what it felt it was entitled to. The entire industry deserves high commendation for the spirit of compromise and cooperation it displayed in reaching agreement and making possible the enactment of legislation this year. Without such agreement, it is almost certain that such legislation could not have been enacted this year and the result might have been a considerable period of uncertainty in the industry. Any attempt by one segment of the sugar industry at this time to obtain a larger quota is certain to result in similar efforts by all other segments and the result easily could be to lose some of the advantages which the Act achieves for the industry.

The 1948 Sugar Act retains the same marketing and acreage provisions as those contained in the previous Act. There have been some significant changes in the pattern of sugar beet production in the United States during the last five years. These changes will complicate the problems involved in determining marketing allotments and proportionate shares. Certainly, many of these changes in the pattern of production have been closely associated with developments in technology. Since you have had a very significant influence upon the adjustments in production from area to area, I hope you will have an interest in helping solve the problems which will arise when allotments become necessary again. In mentioning these problems on recent occasions and in stating that it would be the policy of the Department to impose marketing or acreage restrictions through allotments only when the need for such action has been very clearly demonstrated, I have been surprised to have a number of people in the beet sugar industry tell me that they think marketing and acreage restrictions should be imposed immediately. I am not sure I understand their reasons for feeling that such restrictions should be imposed at this time and, therefore, I shall not attempt to describe them. However, you can imagine my astonishment at suggestions from the industry that the Government impose restrictions upon the industry prior to the time the Government believes that such restrictions are necessary to accomplish the purposes of the Act.

The previous Act required the Secretary to make determinations regarding fair and reasonable wages for workers employed in the production of sugar beets or sugarcane and fair prices to be paid by producer-processors for sugar beets or sugarcane purchased from other producers. The new Act, in addition to retaining the provisions of the previous Act, requires that, if requested by a substantial portion of the persons in any producing area, the Secretary shall make recommendations with respect to terms and conditions of contracts between producers and processors and between laborers and producers. The administration of these provisions of the Act relating to wages and prices has always been very difficult, partly because of the tremendous task involved in attempting to obtain and analyze sufficient information on which to base a determination. We are currently

preparing to obtain important basic information regarding production and processing of sugar beets and sugarcane in all the domestic areas.

The task of making such determinations is not a pleasant one and we do not relish it. During the time the bill was under consideration in the Congress there was a considerable amount of discussion regarding proposals to eliminate from the bill the provisions relating to wage and price determinations. The Congress resolved this by leaving the provisions *in* the Act and adding the additional provision regarding determinations requested by a substantial number of persons in any area. Since the provisions are in the Act, we must administer them and we are going to do the best job we can in administering them. This type of job will call for obtaining more information regarding current costs and conditions in producing and processing sugar beets and sugarcane. In obtaining such information I hope we can have your full cooperation because full information on these topics should be as helpful to you as to other segments of the industry and to us. Improvements in technology result in changes in cost relationships in producing sugar beets. Unless proper adjustments are made in the wage and price determinations as a result of such changes in cost relationships, improvements in technology could be retarded because of an improper distribution of the benefits. Therefore, it is to your interests as well as ours to see that the best possible information is obtained as a basis for the determinations.

Recognizing the need for an expanded research program for American agriculture, Congress, in 1946, passed the Research and Marketing Act, commonly referred to as the Hope-Flannagan Bill. This Act provides for a broad national program of research into basic laws and principles of agriculture, including research and services in connection with problems of production, utilization and marketing of agricultural products. The principal objective of the legislation as stated by its sponsors is to assure agriculture a position in research equal to that of industry. Special emphasis is given to the development of new uses for agricultural products, the expansion of present uses, and the improvement of marketing facilities and services to promote a sound, efficient, privately operated distribution system.

The current fiscal year is the first one for which the Research and Marketing Act has been in operation. For work this year a total of $9,000,000 was appropriated. This was divided for various purposes in accordance with formulas included in the Act as follows:

$2,500,000 to the State Experiment Stations.

$3,000,000 to the Department for utilization research.

$1,500,000 to the Department for cooperative research other than utilization (essentially production research).

$2,000,000 to the Department for marketing research and services work.

Allocations of Research and Marketing Act funds within the Department were made on a project basis, just as research funds have been allocated under previous authorities. Some of the projects relate specifically to one or more agricultural commodities, and some are related to research on broad problems such as weed control, insect control, etc., and are known as "across-commodity" projects. However, an agency which receives an allocation for an "across-commodity" project may divide it into two or more subprojects on specific commodities.

Although the views of leaders in agriculture and industry are always considered by the Department of Agriculture and by Congress in connection with research projects, the establishment of industry advisory committees to review and recommend projects under the Research and Marketing Act insures an even closer degree of coordination of such projects with other public and private research work and with the aims and needs of the industry. Obviously, this has increased the responsibilities of industry with respect to such work. The entire domestic sugar industry, from producers and processors to the final distributors and users will surely want to take an active interest in this work.

If this research work is to attain the objectives aimed at it will be necessary for both private and public agencies to address themselves to a solution of the problems and difficulties now standing in the way of progress. During the war research in general had to be directed in large part to the immediate task of achieving military victory. Normal peacetime work in research, as in other fields, was necessarily, and properly, diminished. We must now catch up and forge ahead with the work needed to permit our agricultural industries to achieve their full peace-time opportunities. Fortunately many of the advances made during the war will be applicable in some degree to the post-war work. Many new insecticides need testing to determine their usefulness and safety on crops. A by-product of the atomic bomb provides a new method of studying plant nutrition. Even more important than such individual technical developments, however, the war has resulted in a closer understanding of government by industry and of industry by government than ever existed before. The coordination of effort between industry and government that achieved military victory should be retained in developing the post-war research programs so that government and industry working in their respective spheres, can supplement each other in achieving full utilization of our post-war opportunities.

At the time work started in outlining the Research and Marketing Act projects for 1947-48 the sugar industry as well as the Sugar Branch of the Department of Agriculture was still occupied with rationing and price-control work, purchase and price-support operations, and the need for reenacting the Sugar Act. Only secondary attention could be given to the new research work. Moreover, sugar was still in short supply. Accordingly sugar was not then facing the immediate surplus and marketing difficulties that appeared to confront some of the other agricultural commodities. Even

more important, however, government research in sugar had not been developed during the period between the two World Wars to the extent that it had for certain other commodities, such as cotton. As a result, sugar received directly a small share of the funds for the 1948 fiscal year. Naturally much of the "cross-commodity" research in such fields as insect and weed control, should be valuable for sugar crops as well as other crops. In looking to 1948 and future years it is evident that the sugar industry owes it to itself and to the ultimate consumers to assist in organizing an adequate research program to meet our future needs. The one word of caution that I would stress in this connection is that we emphasize the projects of fundamental importance. There is always danger of confining work to the projects that appear immediately pressing and of neglecting the fundamental work needed for a major improvement in the industry.

For the current fiscal year only two projects on sugar were approved. One of these was a project on "Development of Practices to Maintain Sugar Quality of Harvested Sugar Beets and Sugarcane and to Prevent Pre-processing Losses." The objective of this study is to discover means for reducing sugar loss in sugar beets during the period in which they are stored prior to processing and to discover means for reducing or preventing loss of sugar in and deterioration of sugarcane harvested for milling.

The other sugar project approved for work this year is one on "Competitive Relationships Between Corn Sugar and Sirups and Cane and Beet Sugars and Sirups." The objective of this study is to determine quantitatively for various types of industrial users the use of corn sugar or sirup and dry or liquid cane and beet sugar as sweetening agents; to ascertain the factors governing the choice of use of sweetener; to study the competitive relationship between liquid sugar and corn sirup and the probable effect of the expanding liquid-sugar industry on both the dry sucrose and corn-sirup industries; and to explore the problem of probable longtime market demand for the various types of sweeteners.

A portion of an allotment of funds for a project on "Economics of Farm Mechanization and Other Improved Techniques" is being spent studying the "Economics of Sugar Beet Mechanization." The overall objectives of the portion of the study on sugar beets are: (1) To determine the cost and performance, including the effect upon yield and quality of both sugar beets and sugar-beet tops, of various machines and other innovations used in the production of sugar beets and competitive crops, and the effect upon the quantity and quality of labor required; (2) to appraise the effect of mechanization and related technological developments on the competitive position of sugar beets and on the organization, operation, and income of sugar beet farms in the major producing areas; and (3) to appraise the probable effects of mechanization and associated technological innovations on the agriculture and the people of the major sugar beet producing areas.

One of the projects on which it is hoped that work can be started soon is the utilization of sugar beet tops in the production of beet leaf meal.

An effort was made to get this work started last fall with the Colorado Agricultural Experiment Station. The proposed study includes work on dehydration, harvesting, feed value, and economic aspects of beet-top utilization. The primary objective of the contemplated study would be to determine the possibility and practicability of utilizing sugar beet tops in the production of dehydrated sugar beet leaf meal.

It has been recommended that attention be given specifically to sugar beets and sugarcane under the "cross-commodity" projects on weed control and insect control. The development of detrashing methods for sugarcane should also have high priority in research.

The Department and the sugar industry advisory committee established to advise the Secretary with respect to research on sugar and sugar plants which should be undertaken with Research and Marketing Act funds now are formulating their recommendations for the next fiscal year. It is assumed that the projects under way will be carried to completion. Other projects before the advisory committee include:

1. A project relating to new and expanded uses of sugar and sucrose-containing materials, with emphasis on the utilization of blackstrap molasses for livestock feed, acids, plastics, and other products.
2. A project relating to the development of marketing standards for sirups, edible molasses, and liquid sugar.
3. A project relating to field elimination of trash and foreign matter from sugarcane and sugar beets.
4. A project relating to the plant food requirements of sugar beets and sugarcane.
5. A project relating to breeding and agronomic testing of sugar beet and sugarcane plants for maintenance of quality under a fully mechanized system of agriculture.

It is, of course, too early to know how much money will be appropriated for work under the Research and Marketing Act during the next fiscal year. However, the Act provides for larger appropriations each year until the work can reach its maximum. If that principle is followed the appropriation for next year should be substantially more than the $9,000,000 appropriated for the current year and the portion that will be alloted to research on sugar will undoubtedly depend upon the soundness with which sugar's needs and research programs can be established.

# Report of the Secretary

THE active paid-up memberships in the Society are distributed as follows:

| | | | |
|---|---|---|---|
| **Individual:** | | | |
| Arizona | 3 | Minnesota | 8 |
| California | 53 | Missouri | 1 |
| Colorado | 77 | Montana | 21 |
| Georgia | 1 | Nebraska | 9 |
| Idaho | 28 | New Mexico | 2 |
| Illinois | 6 | New York | 4 |
| Indiana | 2 | Ohio | 5 |
| Iowa | 3 | Oregon | 3 |
| Kansas | 10 | South Dakota | 7 |
| Louisiana | 1 | Utah | 34 |
| Maryland | 5 | Washington | 9 |
| Massachusetts | 1 | Washington, D. C. | 1 |
| Michigan | 23 | Wisconsin | 2 |
| | | Wyoming | 9 |
| Total in United States | | | 328 |
| Hawaii | 1 | | |
| Canada | 18 | | |
| England | 2 | | |
| Eire | 1 | | |
| Denmark | 2 | | |
| Sweden | 2 | | |
| | 26 | | |
| Grand Total | | | 354 |
| Companies, other than sugar processors | | | 2 |

These figures show a gain in individual memberships since the last General Meeting of 92 within the United States and 8 outside the United States.

The Beet Sugar Development Foundation made possible the publishing of the 1946 Proceedings through a subsidy covering the total expenses in connection therewith. To the Foundation we are duly grateful. We also wish to express our appreciation to the Editorial Service of the Colorado A and M College for its services in connection with the publishing of these Proceedings, and to our own Editorial Committee composed of Dr. H. E. Brewbaker, A. W. Skuderna and P. B. Smith.

The proceedings of the 1946 meeting were published and distributed in early 1947. Copies were sent to all active members of the Society, Company members, 18 non-members, 3 United States Government Experiment Stations, 9 university and college libraries, 1 public library, 3 public research libraries, 8 industrial and 25 foreign libraries. Fifteen copies were sent gratis to libraries of organizations doing research work in sugar beets and 12 were sent to organizations on an exchange basis in the United States, Canada, Great Britain and Europe.

Two regional meetings of sectional groups of the Society were held during 1947. The Eastern United States and Canada sections met January 22 and 23 in Detroit, Michigan, and the Intermountain and Eastern Slope sections met February 3 and 4 in Salt Lake City, Utah. Both meetings were well attended. Proceedings of these meetings were published by the respective groups in mimeographed bound volumes and distributed to those in

attendance at the meetings. The Society purchased 100 copies from each regional group in order to care for requests for these publications coming through the office of the Secretary. Seventy-three copies have been mailed to date to interested individuals and libraries upon request.

There are now on hand in the Secretary's office the following Proceedings and other publications of the Society:

| | |
|---|---|
| 1937 Proceedings | 7 copies |
| 1938 Proceedings (Salt Lake City meeting) | 13 copies |
| 1940 Proceedings (2 vols.) Denver meeting | 131 copies |
| 1941 Summary of Sugar Beet Investigational Work in Canada and United States | 55 copies |
| 1942 Proceedings, Salt Lake City meeting | 480 copies |
| 1943 Regional Proceedings, Detroit meeting | 3 copies |
| 1946 Proceedings, Denver meeting | 12 copies |
| 1947 Regional Proceedings, Detroit meeting | 69 copies |
| 1947 Regional Proceedings, Salt Lake meeting | 68 copies |
| Miscellaneous reprints from 1942 General Meeting | |

Respectfully submitted,

January 14, 1948. C. E. CORMANY, *Secretary.*

# Report of the Treasurer

I HEREWITH submit the Treasurer's report covering the 2-year period, January 1, 1946, to December 31, 1947:

**Receipts**

| | | |
|---|---|---|
| From 1946 General Meeting (inc. registrations, misc. purchases) | $ 390.55 | |
| Individual membership for 1946-47 biennium | 895.00 | |
| Company memberships | 20.00 | |
| Sales of Proceedings | 553.00 | |
| | $1,858.55 | |
| Balance on hand December 31, 1945 | 193.04 | |
| Total receipts | | $2,051.59 |

**Disbursements**

| | | |
|---|---|---|
| On expense of 1946 General Meeting | $ 326.69 | |
| On expense of 1948 General Meeting | 70.50 | |
| For service on 1942 Proceedings (Esther Horsley) | 150.00 | |
| Purchase of 1947 Regional Proceedings | 300.00 | |
| 150 copies of Eastern U. S. and Canada Regional Proceedings | | |
| 150 copies of Intermountain and Eastern Slope Regional Proceedings | | |
| Stationery and printing | 278.57 | |
| Postage | 162.53 | |
| Express on Proceedings | 15.45 | |
| Stenographic services | 100.80 | |
| Miscellaneous (inc. telephone, bank charges) | 11.46 | $1,416.00 |
| Balance on hand December 31, 1947 | | $ 635.59 |

Respectfully submitted,

C. E. CORMANY, *Treasurer.*

# Report of the Resolutions Committee

SAN FRANCISCO MEETING

JANUARY 14, 1948

THE FIFTH General Meeting of the American Society of Sugar Beet Technologists being held in the Palace Hotel in the City of San Francisco is the most widely attended of any meeting held by this Society and the scope of its programs has been unsurpassed in diversity of subjects and quality of material presented.

We recommend:

1—That the Society extend congratulations and a vote of thanks to its retiring President H. E. Brewbaker and other administrative officers including its Advisory Council for the management and success of this outstanding meeting.

2—That special thanks be extended to the General Meetings Program Chairman, Lyle D. Leach, and his efficient Sectional Program Chairmen for the organization, preparation and presentation of the remarkably fine program material.

3—That the sincere thanks of the Society be given to each speaker, co-authors and others who cooperated in the preparation and presentation of papers at this meeting.

4—That the membership of the Society pledge its whole-hearted support and cooperation to Phillip B. Smith and the various Section Chairmen who now face the important but difficult task of assembling and editing the Proceedings of this meeting in order that all members may share in the benefits of these contributions to our Society at as early a date as possible.

5—That the Society express its deep appreciation and thanks to the Local Arrangements Committee and others who have participated, for the splendid facilities provided for the entertainment, convenience and comfort of the members of this Society, its friends, guests and ladies during the Fifth General Meeting at San Francisco.

6—We further recommend that we express appreciation to the management of the Palace Hotel for the splendid facilities placed at our disposal and to the representatives of the Press of San Francisco for reporting the programs of this meeting.

7—That the Society express its heartfelt appreciation and thanks to our retiring Secretary-Treasurer, C. E. Cormany, who has served us so efficiently, generously and unselfishly for so many years.

8—That the Society express its deep appreciation for the very helpful and timely cooperation of the Beet Sugar Development Foundation in

making it possible to have the Proceedings published and distributed to the Society's membership and that the Secretary be instructed to send a copy of this resolution to the President of Beet Sugar Development Foundation.

Respectfully submitted,

H. L. FLETCHER
R. T. NELSON
H. B. WALKER, *Chairman.*

January 14, 1948
San Francisco, California

THE SOCIETY during the past 2 years has lost through death a number of valuable members and friends for whom the following tributes have been prepared:

| | |
|---|---|
| George M. Bradford | 1876 - 1946 prepared by H. L. Fletcher |
| A. J. Denman | 1883 - 1946 prepared by A. W. Skuderna |
| Hatler Gearheart | 1895 - 1947 prepared by W. Y. Cannon |
| Ernest M. Mervine | 1887 - 1946 prepared by S. W. McBirney |
| Forrest R. Immer | 1899 - 1946 prepared by H. K. Hayes |
| Frank S. Ingalls | 1881 - 1947 prepared by W. Y. Cannon |
| Albert Isaksson | 1895 - 1947 prepared by R. T. Nelson |

We recommend these tributes be published in the Proceedings of the Society to record "In Memoriam" the devotion of these deceased members and friends to the objectives and ideals of this Society, and we further recommend that the Secretary of the Society be instructed to send a copy of the tribute "In Memoriam" to the nearest direct relative of each of the deceased.

## "IN MEMORIAM" TRIBUTES

### GEORGE M. BRADFORD
### 1876 - 1946

The sudden passing of George M. Bradford leaves a void in The American Society of Sugar Beet Technologists which will not easily be filled. He was born in Fredonia, N. Y., December 11, 1876. At the age of seven his family moved to Bay City, Michigan.

The late Mr. Bradford was a graduate of Michigan State College and was, for a time, agronomist for the Columbia Sugar Company. The deceased became agronomist for Monitor Sugar at that company's inception, and it was in this capacity that he carried out important research on the development of strains of sugar beets adaptable to muck soil. He, also, conducted valuable experiments in relation to proper fertilization of muck soils for sugar beet culture.

A patient and exacting scientist, the late Mr. Bradford was respected for his modest and kindly personality and for his valued assistance to younger men in the beet sugar industry.

## A. J. DENMAN

### 1883 - 1946

The passing of A. J. Denman at Grand Island, Nebraska, in July of 1946, marks the loss of another veteran in the sugar industry, in which he had served for 48 years. Born near the place of his death in 1883, Mr. Denman started out as a sample boy and was, through successive promotions, brought up to the capacity of manager which position he had held for the past 30 years.

He valued his associations with The American Society of Sugar Beet Technologists and he prized highly the plaque received from the Society as an award to members serving 40 years or more in the industry.

He was probably the first to use commercial fertilizers on a large scale in sugar beet growing. As early as 1923 he used these, based upon cooperative work by industry and government. He maintained throughout his active life a high respect and enthusiasm for research, and he has left a stimulating influence on progressive field studies in the South Platte Valley areas of Nebraska.

## HATLER GEARHEART

### 1895 - 1947

The American Society of Sugar Beet Technologists has lost one of its long-time members in the passing of Hatler Gearheart.

Hatler Gearheart was born in Amba, Kentucky, April 17, 1895, and passed away at Chinook, Montana, October 25, 1947. He was educated in the schools of Kentucky, graduating from the business college of Bowling Green. He came West and joined the staff of the Utah-Idaho Sugar Company at Sugar City in 1916 as a repairman. At the time of his passing he was District Manager for the Utah-Idaho Sugar Company at Chinook, Montana, a position he had held for approximately 12 years. He has been extremely interested in the development of the beet sugar industry and has devoted his entire time and energy to this work.

Mr. Gearheart has attended every general meeting of the Society since its founding and has been in attendance at all of the Mountain States Regional Meetings. His presence will be sorely missed.

## ERNEST M. MERVINE

### 1887 - 1946

With the passing of Ernest M. Mervine, The American Society of Sugar Beet Technologists has lost an able engineer and an authority in the field of sugar beet machinery.

Mr. Mervine was born March 30, 1887, at Milton, Pennsylvania, and received his engineering degree at Lehigh University in 1909.

One of his most worthy attributes was his ability to hold his counsel until the opportune time, and then by personal influence, draw together the different opinions of thinking men, so that they agreed upon a co-operative plan of procedure.

Applying his golden rule philosophy in his work, he was always ready to lend a helping hand. Making the machine the servant to perform more efficiently the work of man, was his professional desire.

He was a charter member of The American Society of Sugar Beet Technologists and has made many valuable contributions to the Society's work.

## FORREST RHINEHART IMMER

### 1899 - 1946

Forrest Rhinehart Immer, a friend of and cooperator with The American Society of Sugar Beet Technologists, died at St. Paul, Minnesota, February 2, 1946. At the time of his passing he was associate director of the Minnesota Experiment Station and professor of agronomy and plant genetics at the University of Minnesota.

Born at Spencer, Iowa, July 18, 1899, he moved with his family to a farm near Jeffers, Minnesota, while he was still quite young. After serving in World War I he studied at the University of Minnesota where he received his Ph.D. degree in 1927. He taught at his Alma Mater until 1930 when he joined the staff of the Division of Sugar Plant Investigations of the United States Department of Agriculture as associate geneticist, serving in this capacity until 1935.

In 1935 he rejoined the University of Minnesota staff and through successive advancements attained the positions he held at the time of his passing. Dr. Immer was a man of broad experience, an excellent teacher, a wise and helpful consultant and a capable administrator. His loss is keenly felt by members of our Society.

## FRANK S. INGALLS

### 1881 - 1947

In the passing of Frank S. Ingalls, The American Society of Sugar Beet Technologists and the entire beet sugar industry has indeed lost a true friend and an untiring worker. He was one of the group instrumental in founding this Society.

Mr. Ingalls was born in San Francisco, October 16, 1881, and died in Salt Lake City on January 17, 1947. Educated in the schools of Lehi, Salt Lake and the University of Utah, he began what was to become his life's work with Utah-Idaho Sugar Company in 1903. At the time of his retirement, he was general chemist for the company. During his entire career in the sugar industry, he devoted his entire boundless energy and keen mind exclusively to the problems of the industry. Although he modestly disclaimed all merit to any literary recognition of his achievements, his name became synonymous with high quality technical work and unquestioned personal integrity. He was a member of several of the technical societies of the country.

All of us will remember the courteous kindly man with the acutely inquiring mind who was a friend to so many and who so many called "Friend." We can think of no better tribute than to say, "He was a gentleman."

## ALBERT ISAKSSON

### 1895 - 1947

In the passing of Albert Isaksson, The American Society of Sugar Beet Technologists and his many friends thereof lost a careful, diligent worker and earnest companion. Mr. Isaksson was born August 30, 1895, at Kvarnaker, Dala-Jarnä, Sweden. He received his advance training from the Agricultural College at Alnarp, Sweden, and obtained the degree of bachelor of science from that Institution in the year 1921. After much practical experience in the agriculture of Sweden and that gained in travels through Germany, Czechoslovakia and Austria, Mr. Isaksson came to the United States in the summer of 1925. In July 1926, he became associated with the Experiment Station at Longmont, Colorado, and was actively engaged in agricultural research for The Great Western Sugar Company until the time of his failing health. His death occurred June 26, 1947, while visiting relatives in Dala-Jarnä, Sweden. Mr. Isaksson's major contributions were in the field of plant pathology. Besides being a student of nature, he was very interested in literature, art and music. He was a charter member of The American Society of Sugar Beet Technologists and maintained his membership and support of the Society continuously.

# Recent Developments in the Control of Weeds

W. W. Robbins[1]

The period from 1940 to 1948 has brought more revolutionary changes and improvements in weed-control methods than in all previous agricultural history. Reference is made here particularly to chemical methods as contrasted to non-chemical methods. The shortage and high cost of labor, the high price of most farm crops, and the rather rapid spread of certain primary noxious weeds—all of which occurred during the war period—created an urgent demand for such changes and improvements.

The three great enemies of agricultural production are insect pests, fungous diseases, and weeds. For many years we have spent huge sums for research to find means of combatting insects and fungi which infest crop plants; annually, we have expended millions of dollars for insecticides and fungicides. All through history, weeds have been taking their toll, and, comparatively, we have done little or nothing about it. We have taken weeds for granted; that, like bad colds, they have always been with us, and there is nothing we can do but live with them and tolerate them.

Within recent years our viewpoint has changed; weed control is receiving greater emphasis; there is more research and increased educational effort; and there is more serious consideration of the problems involved on the part of both growers and of manufacturers of herbicides and equipment.

There is a growing realization that the production of almost all crops is largely a battle with weeds; that weeds are often the main factor responsible for decreased yields, for increased cost of labor, for impairment of the quality of farm products, for depreciation of land values; and that weeds too frequently harbor the very insects and fungi which attack crop plants.

Another change of viewpoint is evident. I refer to planned methods of weed control which extend over several years and have as their objective the almost complete eradication of weeds from certain areas. Instead of temporizing with weeds, using half-way measures year after year with no perceptible lessening of the infestation, we see in operation programs which gradually reduce the annual costs of weed control. These call for the use of pure seed, for cleaning up the sources of infestation, such as fence lines, roadsides, ditchbanks, and waste places, for the use of chemicals, now available, which are more than top-killers of perennials, for the use of soil sterilants, and the judicious timing of seasonal cultural and other operations which eliminate the maturing of weed seeds.

These are not idle dreams. The objectives just mentioned are being realized in many places. Fields once weed-infested are now weed-free. We are well on our way toward solving, in a practical way, the age-old problem of weeds. New materials and new methods, developed during the last few years, have made this possible.

[1]Botanist, Division of Botany, College of Agriculture, University of California, Davis, California.

Let us summarize the recent progress in weed-control methods:

## I. Selective Herbicides

The use of selective weed-killers has become standard practice. We now have selective herbicides for the control of weeds in all the small cereals, including rice; in corn and milo; in lawns and pasture lands; in carrots, celery and related crops; in peas, flax, onions, and garlic; and in alfalfa, both old stands and seedling stands. The principal selective herbicides now in use commercially are (1) certain dinitro compounds (salts of dinitro-orthocresylate and ammonium salt of dinitro-ortho-secondary-butyl-phenol); (2) certain oils (stove oil or special fractions having a gravity rating in A.P.I. units of 37° or above (Shell Weedkiller No. 10 and Standard Weedkiller No. 1); and (3) both inorganic and organic salts of 2, 4-D (2,4-dichlorophenoxyacetic acid). In addition to the three principal groups of selective weed-killers just mentioned, others show some promise, particularly isopropylphenyl carbamate (IPC), phenylmercuric acetate, and ammonium trichloro-acetate.

The selective dinitro compounds find their greatest use in the control of weeds in small cereal crops (excluding rice), in peas, flax, onions, and seedling stands of alfalfa; the oils in carrots, celery and related crops, and in established stands of alfalfa; the 2,4-D compounds in all cereal crops, in corn, milo, lawns, and pasture lands, and in the control of many different shrubby species. IPC has shown promise for use in destroying certain grasses without serious injury to broad-leaved crop plants associated with them; phenylmercuric acetate has been used in a limited way to control crab-grass in bluegrass lawns; and ammonium trichloro-acetate is destructive to certain grasses but not to some broad-leaved crops.

With the exception of the three last-mentioned chemicals, the others listed above are now being sold in hundreds of thousands of pounds and/or gallons annually; and it is safe to say that in 1948 several million acres of crops were treated with selective herbicides. Within the last 2 or 3 years a whole new industry has been created. Nearly all of the major chemical manufacturers are in heavy production; and most of these weed-killers may be purchased in all cities and towns of the country. Who knows but that the volume of herbicide business may equal in a few years that of either insecticides or fungicides?

The selective or differential action of many of the new herbicides is not necessarily due to differences in the structure and in the nature of the surfaces of plants. We now recognize that species tolerance or susceptibility to a given chemical may be due to the effect of the substance on the plant's metabolism. For example, the foliage of carrots absorbs oil but the cells tolerate it; and representatives of the grass family are relatively insensitive to quantities of 2,4-D which are lethal to members of many other plant families. Even among the grasses, some are more sensitive than others to 2,4-D. In these cases, it is known that 2,4-D penetrates the surface cuticle and enters living cells. And, among broad-leaved plants

belonging to the same family, some species may be sensitive to 2,4-D while others are not. In our search for selective herbicides, especially among the plant growth-regulating substances, we may discover a great many chemical compounds which will answer specific agricultural needs in destroying this or that weed without injury to this or that crop plant.

### II. General-Contact Herbicides

These weed-killers are designed to destroy all kinds of vegetation—both weeds and crop plants. They are used to control undesirable plant growth along highways, rights-of-way, and fence lines, and around farm and industrial buildings. There are three types of general-contact herbicides: (1) water-soluble materials, (2) oils, and (3) emulsions of oil and water. The principal water-soluble general contact weed-killers are sodium arsenite and sodium chlorate; the principal oils are diesel fuel, smudge-pot oil, stove oil, kerosene distillates, and various low-grade oils.

The significant progress in the development of general-contact herbicides has been the introduction of several new chemicals—certain phenol compounds such as pentachlorophenol, dinitro-cresol, dinitro secondary butyl phenol, dinitro secondary amyl phenol, and their salts. Examples of these products are "Sinox General" and "Dow General" weed-killers. These phenols are now used extensively to fortify oils; they increase the killing power of the mixture where an oil is being used in emulsion, or in low-volume applications by airplane. These fortified oils destroy certain oil-resistant weeds, such as sweet fennel, yellow star thistle, mayweed, and pineapple-weed.

### III. Pre-emergence Sprays for Weed Control

Considerable attention and emphasis have been given recently to the control of weeds in row crops by pre-emergence chemical treatments. Two methods of attack have been employed: (1) application of a selective herbicide to the soil at the time of seeding. The chemical in the soil kills weed seedlings, but those of crop plants are uninjured. In England, 2,4-D and related growth-regulating substances have been so employed to control broad-leaved weeds in cereal crops. (2) Application of a general contact herbicide to a population of weed seedlings prior to the emergence of crop seedlings, or prior to the seeding of the crop. Under certain soil and weather conditions, slowly emerging seedlings, like those of onions, may be preceded by a dense stand of weed seedlings. It may be advantageous and economical to destroy this weed population by using a chemical which is lethal to all types of weeds, including grasses. The crop seedlings later emerge and make their early growth free of weed competition. Moreover, the cost of hand weeding may be substantially reduced. Under other conditions it may be desirable to allow a crop of weeds to develop, drill the seed right into the young weeds, and then destroy the weed population before crop seedlings emerge.

Pre-emergence weed control recognizes the fact that, as a rule, only those weed seeds that are within the upper one-fourth to one-half inch of soil germinate; and that if the initial population of weed seedlings is destroyed, without further tilling the soil, and thus bringing more weed seeds near the surface, very few weeds will later be present to interfere with the early growth of the seedlings of crop plants. Pre-emergence weed control also recognizes the fact that the early competition of weeds with crop seedlings is a factor of great significance; that the competition underground is quite likely more severe than that above ground; and that vigorous, healthy development of crop seedlings is enhanced by the absence of this root competition.

If pre-emergence chemical weed control is to be of maximum benefit, and yet economical, application of the materials must be made when the weeds are very small—from one-fourth inch to one inch tall. At these stages the weeds are easily killed, the volume of materials required is low, and competition is eliminated early.

### IV. Low-volume Application of Herbicides

It is difficult to overrate the value of low-volume application of weed-killers. This has been a most significant recent development in weed control. Such low-volume applications have been made possible by the development of suitable equipment and nozzles, and by the discovery of the growth-regulating types of herbicides. Formerly, chemicals available and suitable for control of weeds in cereals, for example, called for rather complete coverage of the foliage, and consequently for a large volume of material, usually from 100 to 150 gallons per acre. Hence, hauling and refilling added greatly to the cost of application, and also precluded the use of the airplane. In contrast, effectiveness of 2,4-D does not require full coverage of the foliage surface, and low-volume applications are made possible. In those cereal sections of the country where sources of water are few and far between, low-volume application of weed-killers is imperative if costs are to be kept within reason.

The fortifying of oils has also enabled the use of low-volume applications of general contact herbicides. With ground rigs, equipped with small-aperture nozzles, running at low pressures (20 to 60 pounds), and at high ground speed, it is now possible to reduce the effective volume of contact herbicide applied per acre to as low as 10 gallons. Fortified oils also lend themselves to airplane application. It must be emphasized that if low-volumes are to be effective, they must be applied to very small weeds—a practice which usually is advisable under all circumstances.

### V. Non-cultivation of Orchards and Vineyards

Some 50,000 acres of citrus groves in southern California are operating under a system of non-cultivation; weeds are kept under control by general

contact herbicides. A few of these groves have not been cultivated for 18 to 20 years, and many for 10 to 12 years. The costs the first few years were high but they rapidly decreased during succeeding years. The soils in these orchards have improved as to structure, water-penetration has increased, repeated applications of the herbicides (chiefly oils) have left no injurious residues in the soil, and the general vigor of the trees and quality of fruit have been entirely satisfactory. Moreover, repeated applications of contact herbicides have eliminated such perennials as Johnson grass, morning-glory, and Bermuda grass. Olive and vine growers are also showing great interest in non-cultivation, substituting chemicals to control the weeds. Fortified oils are indicated as suitable materials for weed control in orchards: with these we may reduce costs per acre.

## Summary

Emphasis has been placed in this discussion on recent developments in chemical methods of weed control. Without detracting from the importance of such methods, it needs be said that cultural operations, suitable implements, and proper timing in their use, and crop rotation—in short, GOOD FARMING—will always be approved and highly recommended as a method of practical weed control.

As regards weeds and their control, and as compared with a few years ago, there is greater interest on the part of growers and of manufacturers of herbicides and equipment; there is more research and education; a keener realization of the importance of weeds from the standpoint of food production; more effective regulatory measures; and, above all, a degree of progress in the whole field of weed control which has changed the attitude of growers: today they are realizing that weeds need not be tolerated, that weedy fields can be changed to weed-free fields, and economically so.

Recent progress in weed-control methods involve: (1) selective herbicides, (2) general contact herbicides, (3) pre-emergence sprays and dusts, (4) low-volume applications of herbicides, and (5) non-cultivation of orchards.

The principal selective herbicides are: dinitro-compounds to control weeds in small cereals (excluding rice), in flax, peas, onions, and seedling stands of alfalfa; certain oils to control weeds in carrots, celery and related crops, and in established stands of alfalfa; and 2,4-D compounds to control weeds in all cereal crops, in corn, milo, lawns and pasture lands, and in the control of certain woody species. In addition, several other selective herbicides are showing promise, namely, isopropyl phenyl carbamate, ammonium trichloro-acetate, and phenyl mercuric acetate.

Certain toxic phenol compounds are of great importance as fortifiers of oils. Fortified oils make oil-water emulsions feasible and the use of less oil per acre.

Pre-emergence sprays and dusts are finding use in the control of weeds in row crops.

The development of certain herbicides and the improvements in equipment for their application are making possible low-volume applications.

Every year sees an increase in the acreage of orchards and vineyards in which chemical methods rather than cultural ones are used to control weeds.

# Fertilization of Sugar Beets

OMER J. KELLEY[1]

NEARLY EVERYONE in this room has at one time or another been confronted with the problem of sugar beet fertilization in a given region, on a certain farm, or on a particular piece of land on a farm. This fact puts us all on the same common ground, and I am sure each of us has some ideas on how to fertilize a beet crop, at least in some particular area. After I had been asked to talk on the subject of fertilization of sugar beets, and had reviewed a number of papers, I asked myself, "What do we know about sugar beet fertilization?" Not what are our ideas, or suppositions, but what do we know? I was reminded of an example given by a certain professor of Colorado A & M College at the 26th annual meeting of Colorado Seedmen's Association at Fort Collins, December of 1947. The professor was discussing the fertility problems in Colorado. When the question was raised as to what was known about the fertility problems of Colorado and their solution, the professor raised this bulletin and said, "This small bulletin contains all we know about the fertility problems in this state." He then raised this bulletin and said, "This bulletin contains all we are willing to guess on." And raising his hand above the desk about two feet he said, "This bulletin, which hasn't yet been written, contains all we do not know about the fertility problems in this state." I believe we are in about the same position with respect to our knowledge on fertilization of sugar beets.

To be sure there is a tremendous amount of experience, experimentation, and research back of us. A great deal of information and knowledge has been obtained from this past effort. But when we compare this with what we do not know, the difference is great.

What are the important soil fertility problems of the sugar beet producer? They are numerous and if broken down in detail would require several pages for their listing. Most of the specific problems, however, would be combined in a typical answer which a farmer would give if we were to ask him to state his problems in regard to fertilization of sugar beets. He would say that he wanted to know how to fertilize his particular piece of land in order to get a maximum economic return from his investments, including his labor. In other words, the practical problem is to be able to tell every farmer what fertilizers to apply, how to apply them, and the correct amount to apply.

How can these questions be solved? There are at least two ways of approach. First, we could conduct experiments on every farm and even every soil type on every farm in the sugar beet growing areas to try to obtain the correct answers. Second, we could develop some means of

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analyzing the soil to predict fertilizer needs for various crops under different conditions. Let us consider first the approach of conducting field experiments on all of the farms. We know from past experiences that no two farms are alike, and that information obtained on one farm cannot be translated to another farm without considerable information on the soil, most of which we do not know how to obtain. Even if we were to conduct fertility experiments on every piece of land that was to be put in sugar beets the results at any particular spot would vary from year to year depending upon past treatment, previous crops, etc. Of course, we know that we do not have money enough to attempt such a program and that it would be an unwise approach if we did have the money. I am sure no one has ever tried or anticipated such a program. Field experimentation is necessary, however, and a certain amount of it must be done.

Let us look at some data from fertility experiments, conducted in Colorado by the Great Western Sugar Company and the Colorado Agricultural Experiment Station (3)[2]. These results were presented and discussed Monday afternoon in the Irrigation and Fertility Section. The fertility experiment I am referring to had various treatments, but included were three levels of nitrogen at the following rates: 0, 66, 132 pounds of nitrogen per acre and two levels of $P_2O_5$ at 0 and 120 pounds per acre. This experiment was conducted at 37 locations. Of these 37 locations, 70 percent gave increases in sugar per acre from the added phosphorus. Variations in apparent response varied from a minus 1,100 to a plus 1,300 pounds of sugar per acre. There were 2 farms on which the added $P_2O_5$ apparently reduced the yield by 1,100 pounds of sugar per acre and 2 farms on which the added $P_2O_5$ increased the yield of sugar by 1,100 or more pounds per acre. Part of these differences may be due to errors inherent in field experiments. For plots receiving 66 pounds of nitrogen per acre there were 51 percent on which yields were apparently decreased and about 49 percent on which yields were apparently increased. Variations associated with this treatment were from minus 700 pounds to a plus 1,700 pounds of sugar per acre. When nitrogen was added at the rate of 132 pounds per acre but in combination with phosphorus and potassium, 57 percent of the locations gave increases and 43 percent gave decreases in sugar production. Variations were from a minus 1,900 to a plus 1,700 pounds of sugar per acre. Certainly different responses at different locations were expected from the various treatments by the people who designed these experiments. They do serve, however, to illustrate the fact that the mere conducting of field experiments will not completely answer the problem of how to fertilize sugar beets. I know that the Colorado people and others connected with this experiment just referred to are making laboratory and greenhouse studies in an attempt to obtain more information on these soils and reasons for the type of responses obtained.

In 1945 Bion Tolman (4) of the Utah-Idaho Sugar Company conducted an experiment with uniform treatments at 55 locations. These

[2]Numbers in parentheses refer to literature cited.

tests covered an area of four states—Utah, Idaho, South Dakota, and Washington. The chemical treatments were 0, 200, and 400 pounds of ammonium sulfate and treble superphosphate each in all combinations at every location. For our purpose we shall consider these as treatments 1 to 9 and observe the data with respect to uniformity of response to any one treatment. The data as summarized by Tolman indicate the most profitable treatment for each location. The individual locations were broken down into states and in most cases into districts. Some typical examples are given. In the Gunnison District of Utah there were 8 locations. The highest percentage of fields for most profitable treatment came in the Number 1 treatment, no added fertilizer, and in treatment Number 3, 400 pounds of ammonium sulfate per acre. Thirty-seven and one-half percent of the farms were in each of these two treatments. For the West Jordan District there were 10 farms; the highest percentage of farms in the treatment being most profitable was 30 percent. For Idaho there were 5 districts. The Blackfoot District had 4 farms and 2 of these had the most profitable response from the same treatment, making 50 percent in one treatment. For the Valley District there were 3 farms and all 3 fell in separate treatments for the one most profitable. There were other locations in Idaho but summing up the 21 locations in Idaho, the most profitable treatment was most profitable 38 percent of the time. For South Dakota there were 8 farms. The no added fertilizer was most profitable on the greatest number of farms for a total of 37.5 percent. In the Yakima Valley in Washington there were 8 farms. The 400 pounds ammonium sulfate plus 200 pounds treble superphosphate was the most profitable on 5 of these farms, or 62.5 percent of the time. Summing up all of the 55 locations, there was one treatment that was most profitable on 27.3 percent of the farms; all of the rest were less.

A summary of the data in the manner just given is somewhat different from the summary given by Tolman and may be somewhat misleading insofar as practical application is concerned. For instance, often the differences between treatments in a test were not fundamentally different. There were cases where the 200 pounds of ammonium sulfate plus 200 pounds of treble superphosphate was better than the 400 pounds of ammonium sulfate plus 200 pounds of treble superphosphate and vice versa. At the same time both of these treatments may have returned $4 to $6 for each dollar spent, and this may have occurred on 70 to 80 percent of the farms of a given district. Certainly the benefits to be derived from such experimental work are obvious, and the results of this type of information should be brought to the farmer as quickly as possible.

While the information obtained in the two experiments referred to above is certainly valuable and gives us a better knowledge of the fertility problems in certain areas, it is not the final goal in our desire to obtain information on the fertility problems of sugar beets or fertility problems in general. More information is needed. Why is there such variation in response to treatments? The answer is that there are any number of factors

that affect yield. Some of the first thoughts center around such things as past cropping history. Were such crops as alfalfa and other legumes grown? Has the land received large applications of manure or other fertilizer treatments? What about soil type, etc.? Was moisture a limiting factor?

A factorial experiment (2) at the Utah Station was conducted on land that was thought to be quite uniform with respect to fertility level. The variables were moisture, spacing, manure, and commercial fertilizer treatments. This experiment has shown that if one is to obtain a maximum return from added, high amounts of nitrogen it is necessary to have a sufficient number of plants to utilize more fully the large amounts of nitrogen added. For instance, in this experiment, compare the yields of sugar from plots which received no added nitrogen with those from plots which received 160 pounds of nitrogen at each of the three spacing treatments. On the no-added-nitrogen plots the yields of the 12-20 inch and 20-inch spaced rows yielded the same—about 3.4 tons of sugar per acre—but for the plots receiving 160 pounds of nitrogen the yields increased for the 24, 20, and 12-20 inch spacing as follows: 3.35, 3.95, and 4.25 tons sugar per acre respectively. Likewise, there was not a sufficient number of plants on the 24-inch spacing to benefit from the extra 80 pounds of nitrogen in the 160-pound treatment versus the 80-pound treatment. In the nitrogen treatments at the various moisture-stress levels it was found that for the 160-pound nitrogen treatment the low stress (or high moisture) yielded 4.25 tons sugar, the intermediate or next driest treatment yielded 3.4 tons sugar per acre and the driest treatment yielded 2.9 tons sugar per acre. In this experiment it was very obvious that nitrogen was an effective fertilizer only if moisture did not become limiting, and it was more effective the greater the number of plants per acre. In other words, if one is to obtain a maximum yield or a maximum economic use of fertilizer it is necessary to have all of the other factors that affect plant growth at as near optimum as possible. If any one of the factors affecting plant growth is limiting maximum yields will not be obtained. This experiment has shown highly significant interactions between moisture level, spacing, and fertility treatments, and points out the tremendous importance that moisture level or spacing of plants may have on fertilizer response and yield of beets.

All of these factors we have been discussing are important, but let us raise the question: What is it we really need to know before we can intelligently lay out a fertilizer program for sugar beets in any given area? First we must know the nutritional requirements of sugar beets. We must know for the various periods of their physiological development the nutritional requirements of the various elements, or for instance: What are the needs of beets for phosphorus each week, or month, from the time they are planted until they are harvested?

The total amount of the various elements for certain yields of beets has been determined at various locations for specific conditions. For instance, in a recent paper Gardner (1) has given values for a 15-ton crop of beets and a 3,200-pound crop of beet tops as follows: 134.6 pounds of

nitrogen, 18.2 pounds of phosphorus, and 201 pounds of potassium. Figures are also given for calcium, magnesium, sulfur, iron, manganese, zinc, copper, and boron. While such information may give the total amount of a given element needed for a certain yield, under a given set of conditions, it does not tell the rate of uptake and the specific needs at various periods of the plants' development. Such information can be determined for specific conditions, with our present knowledge.

Second, how much of the various nutritional elements are available in the soil for growth of sugar beets? How much will become available over the growing season? And at what rates? If there is not a sufficient amount of a given nutritional element, how much will need to be added? When some is added, what happens to it? How much will remain available? How much will be fixed in an unavailable form, leached, or become unavailable in some other way? At what rate will it become unavailable? With this type of information, the amount of a given nutritional element required for maximum economic sugar beet production could be added to a given soil. Obviously, we cannot answer these questions at the present time. One of the main reasons for our inability to answer these questions is that we do not know the property of the various elements that is important insofar as plant growth is concerned. Take phosphorus, for instance. Is it total soil phosphorus, water-soluble phosphorus, some acid or alkali extractable phosphorus or some other property that is important insofar as plant growth is concerned? I believe this is one of the first questions to solve. It is not an easy one. Contrast our knowledge on fertilizer elements with that of soil water. We believe now that we know the property of soil water that is important insofar as plant growth is concerned. That is, namely, the total equivalent stress. It was not very many years ago that soil moisture was reported, for various moisture experiments, as so much percentage moisture without any relation to total stress or moisture potential. As we all know, some soils may be at "field capacity" at a moisture percentage of 10 percent while others may be approaching the wilting percentage at values of 15 to 20 percent.

Obviously we could not correlate and integrate various results if our only knowledge of the soil moisture was that of percentage moisture. But once the important property of soil water in relation to plant growth was established, it has been possible to begin to determine the effects of variations in this property on plant growth. These effects will be the same for various soils and various locations providing other factors affecting plant growth which would cause interactions with soil-moisture stress do not vary. We need some such property for the various fertilizer elements—a property that we could determine, the value of which would not vary, insofar as plant growth is concerned, for various soil conditions.

A considerable amount of experimental work should be under way on these fundamental problems. I doubt if there is any one of us who would say that he could even set up an experiment that would definitely give answers to these questions. This, however, should not discourage us

from tackling the problem. Many people have worked on these problems and much information has been obtained. It is becoming obvious, however, with the accumulation of more and more data that these problems are large, and that no one person is going to solve them. Their solution requires more money and more effort than any one or small group of people will be able to put into it. It requires the best and coordinated efforts of all concerned. Developments in the past few years have shown considerable progress.

The establishment of the Beet Sugar Development Foundation indicates a coordinated attack on the research problems by the sugar companies. A similar coordinated approach on soil research problems is indicated by the recent development of a Western States Soil Management Committee which helps to coordinate the efforts of the various state and federal research agencies. This type of coordinated effort makes possible a much more vigorous attack on specific problems. Even with such cooperative approaches, most frequently there is not sufficient technical manpower and funds to undertake the type of research which is known to be needed for the solution of certain specific problems such as the fertilization of sugar beets. I feel certain that we shall not be satisfied with our knowledge on the problems of fertilization of sugar beets until such a time comes when we can analyze a farmer's soil and tell the farmer how much of the given nutritional elements he should add for maximum economic production, where to place them, when to add them, etc. These answers will come only through continued cooperative research, and a redoubling many times of our efforts will be necessary before we obtain the final solution.

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# A Resume of Sixteen Years of Sugar Beet Machinery Research

H. B. WALKER[1]

THE CALIFORNIA Agricultural Experiment Station in 1930 became interested in the opportunities to mechanize sugar beet production particularly those phases where labor demands created peaks such as for harvesting, and for spring thinning and hoeing. The labor demands, particularly for harvesting, are competitive with many other crops like grapes, walnuts, rice, beans and tomatoes, so it is natural for growers to be most interested in mechanical harvesters. However, the spring labor demand is not unrelated to the harvest labor problem, so in considering a project at the California Station both of these labor peaks received attention. In 1931, a cooperative agreement was made with the United States Department of Agriculture to conduct investigations at the California Station under the general title, "Sugar Beet Machinery Investigations," (Project No. 896). This cooperative agreement remained in force until 1943, but the California Station has continued its investigations until this date. The resume presented, therefore, includes research and experimental studies covering a period of 16 years. There were in fact, two periods of activity in this project, (a) the early investigational period extending from the project's inception until mid-1938, and (b), an accelerated research period extending from mid-1938 to date. The only real difference in the importance of these periods is related to the funds available to support the investigations.

The project was supported during the earlier period from State and Federal funds, while during the latter period it received grants-in-aid totaling $114,000 from the United States Beet Sugar Association. The California Station supplemented these funds over the 16-year period by expenditures equalling, or slightly exceeding, the total of the grant. Thus, these funds together with such funds as were supplied through the Federal government, represent a sizeable investment in this field of research. A list of the personnel working at some time or other at the California Station and contributing to this research project, together with their titles and connections, is appended to this paper. Each of these workers deserves credit for the achievements attained. The project was further aided in a consulting and advisory capacity by a committee of industry men representing the United States Beet Sugar Association.

The first period was inherently exploratory due to the limited personnel and funds available, but this should not detract from the importance of these earlier investigations. Mervine, Walker and McBirney explored the labor problems confronting growers during the period 1931-38 and some of the tests and studies of these earlier years formed the basis for the more

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concentrated efforts conducted later. Mervine made the first analytical studies of the blocking and thinning of sugar beets by hand and by mechanical aides. He used a John Deere No. 24 beet cultivator as early as 1931 for cross-blocking trials with various forms of sweeps, shovels, disks and shields. Early results were variable, depending upon the distribution of seedlings. Cross blocking in peat soils was unsuccessful and attempts were made to use chemical cross blocking. Mervine in 1932 made calculations based upon the laws of probability and chance for determining the proper blocker adjustment when the seedling stand had been measured. From these calculations he prepared curves for blocker adjustments when the germination stand is expressed in percentage of inches of row containing seedlings. These curves have been widely used in setting up cross-blocking equipment. They were published in 1933 by Mervine (2) and Skuderna.

During this early period, Mervine at the California Station and later at the Colorado Station, made studies of the relative emergence of seedlings when beet seedballs were planted with planters equipped with disk and shoe-furrow openers. The former gave the better results for whole-seed placement. The practice in California of bed planting and the inability to adapt cross blockers to such plantings led to field tests with "down the row" blockers of which two types were typical; the Uddenborg[2] and the Dixie[3]. Both used rotating members equipped with blades to chop out sections of the row and leave undisturbed blocks of beets as the machine traveled down the row. Where relatively uniform stands of seedlings were obtained, units of this type were satisfactory for thinning in sedimentary soils. Mervine worked with crust breakers, but he was unable to find a unit which had universal application, although many types proved beneficial. These early studies revealed the tendency for beet seedlings to emerge in clumps with frequent gaps in the row. This made thinning to singles difficult and likewise contributed to cross-blocking difficulties. These conditions were caused by the inherent weaknesses of beet drills to provide uniform seed distribution.

In 1932, McBirney considered the potential advantages of planting beet seed in hills, and Rassmann[4] had already designed and constructed planters of this type. The fluted feed drills then commonly used required heavy seeding rates to overcome long gaps in the row. Rates of 15 to 20 pounds per acre were common. The first tests with hill planters in California were made in 1933 with planters using horizontal and vertical plates. These tests, which were repeated the following 2 years, indicated seed-saving possibilities, but stands were imperfect; and in thinning, laborers sometimes pulled out all of the beets in a hill. Losses from this cause ranged up to 20 percent McBirney investigated planter performance with respect to plate fill and found that plate fill decreased with plate speed and with decrease in box fill. In all of these studies, appreciable crushing or milling

[2]Uddenborg, R., Inventor, Fort Morgan, Colorado.
[3]Dixie Cotton Chopper Company, Dallas, Texas.
[4]Rassmann Manufacturing Co., Beaver Dam, Wisconsin.

of the seed was observed. However, he reported in 1936 that: "Planters can be devised to plant in close or scattered hills." He observed further that: "A high percentage of single seedlings in a germination stand was associated with a uniform distribution of seed in planting and that single seedlings contributed to good thinning and reduced time for doing this work." McBirney's objective was to place a single seedball per lineal inch of row. A planter developed by Palmer[5] seemed to offer potentially at least some of these advantages. However, it failed to produce good results under field tests because of variations in seed size, difficulties in seed flow, cell unloading, and the like. This planter was better than the hill-drop, but no improvement over the Planet Jr. No. 3, widely used in California at that time (1936). The results, however, encouraged McBirney to design, build, and test a chain-feed, single seedball planter whereby the chain with cups attached was pulled through the seed reservoir to pick up single seedballs and deliver these near the base of the planter furrow. This development initiated the idea of the single seedball planter and later led to the introduction of the term "precision planting." Walker[6] in September, 1938, reported: "Enough planter work has been completed already to forecast the successful development of a planter which will plant single seeds with controlled spacings."

The harvesting studies during this early period (1931-38), due to the limited funds, had to be confined to tests on machines currently under development, principally by inventors and smaller manufacturers. The problems of harvesting long had been recognized, and many efforts had been made to mechanize this part of sugar beet production. The background of this early development work was reported by Walker (3) to this Society in 1942. Such tests conducted previous to 1938 at the California Station were on such units as the Davis-Thompson, Great Western, and Scott-Viner harvesters. These tests did little more than bring into clearer definition the basic problems involved. Both ground and machine topping was attempted by early inventors with perhaps more attention to the former, but actually more careful engineering development with the latter as evidenced by the Scott-Viner machine. During this period, the standards for harvesting performance were set by hand labor which placed a rather high performance requirement on these early machines. No one during this period had made a really acceptable topper, when judged by the prevailing hand-labor standards, and what was more apparent, no machine had been developed which could successfully separate lifted beets from clods. No ground-topping unit could do an acceptable job of harvesting; and while machine-topping units like the Scott-Viner could do better, it failed to meet grower acceptance. Extensive tests covering a number of crop years were conducted in California with the latter machine, yet it failed to meet grower requirements in California, even though it was more successful elsewhere.

[5]Palmer, P. S., Spokane, Washington, Manufacturer, Cheney Weeder Co., Cheney, Washington.

[6]Walker, H. B., News Letter No. 1 to United States Beet Sugar Association, Sept. 12, 1938. Unpublished data.

In summarizing the studies made at the California Station for this period (1931-38), the following conclusions seem justified:

1.—Blocking by cross cultivation and by down-the-row machines was demonstrated to be practical.

2.—The need of planter development to distribute seeds in the soil regularly was a primary requisite for optimum benefits from mechanical thinning and blocking; and the general specifications for such a planter were conceived.

3.—The separation of beets from clods and a practical method of topping beets were the principal bottlenecks in successful mechanical harvesting with the former far the more important.

Thus, this early work brought into definition the more important of the problems to be solved in sugar beet mechanization. The United States Beet Sugar Association in 1937, largely through the initiative of its intermountain and far western members, became interested in these problems, and in the hope of accelerating their solution, made a grant to the California Station in 1938. The Association, likewise, supported research elsewhere, principally at the Colorado Station, but separate grants were made for these activities. With this added support, it was possible to undertake a much more vigorous program of research, which has been designated as the second period of investigations. In accepting support from industry, the Station realized fully that the research and development work required would present difficult problems. Walker[7] for example, revealed some of the difficulties to be met in defining general specifications for ground toppers in 1939. He stated: "The task (beet toppers) is not an easy one, since a unit of this type must adjust itself rather readily and accurately to (1) high and low yields—5 to 40 tons per arce; (2) high and low beets—that is, with crowns below the surface to 8 inches above; (3) beets of small diameter (1¼ inches) to as large as 10 inches in diameter and in some instances 20 pounds in weight; (4) wet and dry-field conditions; (5) clean and weedy fields; (6) high, brittle tops to low, frozen, dry and second-growth conditions; (7) flat and bed planting; (8) irregular spacings of beets; and (9) the machine must be simple and sufficiently rigid to stand up under rough field handling."

McBirney continued his work with single seedball planters in California, and Mervine in Colorado also developed a single seedball planter of some promise. The John Deere Company started its development work on single seedball planters using a horizontal plate. McBirney made comparative tests with the chain-feed cup, single seedball, experimental planter with 5 commercial types; and he concluded (1938) that while the chain-feed type was superior to ordinary commercial units. it was no better in performance than the improved, single seedball, plate planter. Interest in single seedball planting gained much momentum during this period, and the field results with improved types of plate planters were encouraging.

[7]Walker, H. B. A summary of progress and programs for sugar beet machinery investigations to advisory committee, U. S. Beet Sugar Assoc., Nov. 17, 1939. Unpublished data.

Mervine (1) and McBirney prepared a circular in October, 1938, which recorded developments in sugar beet mechanization up to that date.

During the winter of 1938-39, Bainer and associates in an effort to analyze the accuracy of planter performance introduced the grease-board method of studying seed distribution from sugar beet planters. This simple device was really an innovation which led, ultimately, to significant improvements in planters and seed processing. Many planters were tested, including the chain-feed, and horizontal- and vertical-plate types. The California Station in its August, 1939, report stated: "In addition to producing more uniform stands, the single-seed planters also produced from 20-30 percent more single seedlings than with conventional planters." McBirney further concluded in 1940 that: "The single seedball planter has demonstrated its ability to increase the number of single plants with the result that thinning is an easier operation. . . . Our tests have shown that elaborate planting equipment is not necessary."

As a result of these tests in the laboratory and field, the practice of modifying conventional plate planters to meet the requirements of single seedball planting was established, and by 1940, a number of companies were manufacturing such planters in limited numbers for the farm trade. The experiences with these and the modifications made on fluted feed drills developed troubles from seed grinding in the metering apparatus, and there was still a decided tendency toward bunching of the seeds with attendant skips.

During this period in planter development, harvester studies were also under way. The problems in harvester development were related to the occurrence of doubles and irregular spacings in the row. Bainer, who was interested in both planter and harvester investigations, decided to study further the factors influencing the accurate placement of seeds. Knowing seedballs usually contain more than one germ, he conceived the idea of breaking a multiple-germ seedball into segments in the hope that the segments so produced would provide a seed unit with greater singleness of germ. He had some success in accomplishing this by a "shearing" method, which produced seed units, in number, comparable to the number of original seedball units processed. These approached near unity in seed germs per seed unit, averaging 1.1 germs per unit as compared to 1.9 for the original seed. This method of seed processing, incorrectly termed "shearing" since the seedballs were broken into segments, introduced a radical departure from traditional practices. The method of shearing used by Bainer was first demonstrated at the California Station in May, 1941; and that year, he planted 1 acre with "sheared" seed. He planted plots at low seeding rates, as low as 3.25 pounds per acre. Some of these processed seeds were pelleted. The "sheared" seed germinated satisfactorily and contributed significantly to increased numbers of single seedlings. Pelleting in these early tests indicated no added advantages.

Encouraged by these results, Bainer developed machinery to process whole sugar beet seedballs into segments at a rate of 125 pounds of whole

seed per hour. This product was cleaned by use of a fanning mill and graded on a gravity table. His recoveries were not high, and he advocated the up-grading of processed seed through the elimination of light ends. Leach, working with Bainer, successfully developed methods of seed treatment for this new form of seed.

This pioneer work by Bainer and Leach opened up new fields of attack for planter development. The farm-labor problem was acute at this time due to foreign wars and the threat of war in this Nation. The sugar industry immediately recognized the potentialities of using segmented seed. From the single acre planted in 1941, 10,000 acres were seeded in 1942; and this was extended to approximately 300,000 acres in 1943. By this time, all of the major beet-sugar processors in the United States had installed beet-seed processing equipment patterned after the original designs by Bainer. The demand for plate planters to plant these processed seeds exceeded the ability of manufacturers to supply during the war years, and many attempts were made to adapt old types of planters for using processed seed in the hope of obtaining the labor-saving benefits accruing from less difficult thinning. These savings were estimated to be approximately 10 man-hours per acre. Due to war conditions which aggravated the labor problems, acceptance was much more rapid than would be normally justified. However, results were generally favorable. Walker[8] warned in 1942 that: "We are still in the cautious phase of seed shearing;" but he also pointed out that "In the planting of seed segments, we are attempting to approach an ideal field stand, where even no subsequent thinning may be required. If this ideal is to be approached, it is essential to have seed of known viability approaching perfection in quality; planting equipment capable of distributing the seed in the soil as required for the perfect stand; and a seedbed favorable for the seed and seeding operation."

Lower seeding rates, down to 2 pounds per acre, were used experimentally. Planters of the plate type were designed for 2 sizes of seed; namely, 11/64 inch to 8/64 inch and 10/64 inch to 6/64 inch. Bainer stated in 1942, "that the greatest gain made through the use of 'sheared' seed is from light plantings." The use of seed of high viability and vitality is magnified by such light seeding rates. Armer and Bainer built an aspirator to separate seed segments on a weight basis. This machine, while simple, was effective in raising the percentage of viable seed recovered by approximately 8 percent.

During this time, Bainer observed continued evidence of planter skips. Some planters showed enough skips to make up as much as 25 percent of the row. Planter plates were restudied and improved, but skips persisted. It was decided that more analytical studies of seed distribution were needed. It was observed that even with hill-drop planting, seeds were scattered in the 34-inch drop down the tube. This led to a lowering of plates which tended to reduce cross trajectories in the seed path.

[8]Walker, H. B. Report to Advisory Committee, U. S. Beet Sugar Assoc., Aug. 1942. Unpublished data.

By 1943, composite estimates made within the industry showed that 60 percent of the plantings that year were grown from segmented seed. The pre-season estimates for 1944 were 80 percent with estimated savings of 5,000,000 man-hours of labor due to less difficult thinning conditions.

Planter performance was generally recognized as a key factor in the successful use of processed seed. In July, 1943, a conference was called at Greeley, Colorado, to discuss the requirements of the ideal planter. It was at this meeting that Carsner[9] pointed out the injury to seed by the segmenting process, as well as seed damage from milling in plate planters. This was a significant critical contribution, since it led to a re-examination of seed processing and further attention to improvements in planters. This conference also emphasized the necessity of producing high-quality seed without excessive losses in the processing methods. Recovery heretofore had been low.

During the winter of 1943-44, Brooks[10] and others at the California Station made extensive statistical analyses of seed metering from plates which had been improved for seed-cell unloading with reduced seed injury and with uniformity of timing in unloading. These studies revealed such plates were capable of metering and unloading processed seeds accurately, thus indicating that seed placement contributing to skips and bunching of seedlings must take place beyond the point of plate unloading. These findings led to a study by Bainer of drop tubes in relation to final seed distribution. He found that uniformity of drop in relation to final position in the soil could be controlled best by small (½-inch diameter), smooth, metallic tubes. These, he found were effective for distances up to 32 inches in drop below the plate ejector. This, likewise, was a significant finding and provided the final element for a planter capable of near precision performance.

With planter elements determined, further attention was devoted to seed processing to reduce injuries as reported by Carsner and to produce uniformly sized and shaped seed units. Leach initiated the idea of using decorticated whole seed, and Bainer developed an experimental decorticating machine. When pregraded whole seed was decorticated and then regraded, the product was not unlike segmented seed. Leach made studies of field emergence with plantings of decorticated seeds, and his data confirmed his earlier observations that through decortication, a better shaped, more viable, more uniform and a more easily planted seed unit could be developed which would produce under actual field environments as many singles per unit of row length as the more roughly processed segmented seed, even though the latter may possess greater singleness of germ. Walker[11] the same year made measurements to determine size variations in segmented and decorticated seeds. He reported: "In sheared seed adhering, cork particles sometimes form more or less translucent knife-like edges to

[9]Carsner, Eubanks, U. S. Dept. of Agri., Riverside, California.
[10]Brooks, F. A., Baker, G. A., Lorenzen, Coby, Lewis, H. D. California Agri. Exp. Sta.
[11]Walker, H. B. Preliminary studies of sizes of processed sugar beet seed, Sept. 1945. Unpublished data.

make such units plate-like or flat in contrast to decorticated seed on which no cork adhered." These studies showed that the smoother, more spherical shape of the decorticated product was advantageous for precision planting.

Bainer then developed decorticating machinery suitable for commercial operations. Large-scale field plantings of these seeds confirmed the earlier conclusions of Leach. Bainer also built a machine in 1946 to reduce the size of whole seed through burr reduction. He concluded: "The quality of seed processed in either case (decorticated or burr reduction) is superior to segmented seed in every respect except the degree of singleness of germ." Seed recovery by these methods was considerably increased, being 50 to 60 percent for decorticated seed and varying from 60 to 70 percent for burred seed.

Thus, seed processing, now almost universally adopted by the industry, is a product of the research in planter development. Seed segmentation was the initial step in this search for a seed unit with singleness of germ. Injury to seed by this method, however, together with low recovery, led to methods less violent, and which provided a better shapefactor in the seed unit for precision planting. Thus, in this evolution of seed processing, the sized, decorticated seed unit has come to the forefront, and plate-type planters have been developed to provide uniform placement of any desired number of seeds per unit of linear travel. These planter improvements consist of properly cast and machined plates, improved "cut-off" and "knock-out" devices and the use of small-diameter, smooth, metallic tubes to carry the uniformly released seeds delivered by the plate, on a direct path at uniform velocities, to the soil.

Seed processed by burr reduction and decortication were planted in widely scattered sections in 1946, and three or more commercial processing plants are now in operation. Commercial precision plate planters are now generally available.

The harvester studies conducted during the second period of this project were limited to tests of such machines as were available; but with more funds for investigations, it was possible to conduct research and development on essential elements of machines. The machines which had been tested up to this time (1938) delivered much trash and dirt with the beets, and the topping quality was not satisfactory. In general, large beets were topped too high, and small beets were topped too low; and none of the machines had facilities to adjust the thickness of the crown cut to the diameter of the beet. Powers, in his research work in 1938, found there was a more or less linear relation between crown thickness and beet diameter. He, likewise, found there was a relationship between thickness of crown to be removed and elevation of crown above the soil surface. From these studies, he concluded: "There is the possibility of controlling the crown cut thickness through a gauging mechanism." The same year, field tests were run on the Liberty, Great Western, Zuckermann, and Scott-Viner topping units, as well as experimental tests on a rotary topper designed by Zimmerman.

The following season, Powers improved his experimental topper, and early tests showed the topping by number was 95 percent acceptable and by weight, 99 percent acceptable. The publicity given to harvester investigations through subsidized research attracted inventors and a few commercial companies to develop harvesters. In addition to those units mentioned earlier, were the Braden, the Alvos and Devey units, the Pueblo harvester, the Walz machine of Avondale, Colorado, which later became the foundation unit for the John Deere harvester, the Oliver digger built for American Crystal Sugar Company, and others.

Rimple at the California Station developed a finger pick-up unit with a special plow. Tramontini, at the same Station, worked on a unique vibrating lifter; and Armer made preliminary studies on beet pick-ups by spikes. Powers concentrated on his variable-cut topper, and he conceived the idea of a vibrating knife to sever crowns from beets, when topping in place. He also conceived a leaf and crown pick-up. Armer devised a variable-cut disk topper based upon the beet-size relationships determined by Powers. This topper was found to be effective in weedy fields. Out of all of this work, the topping problems were brought into clear focus for in-place operations, although much refinement work was still needed.

With harvesters, the clod problem remained unsolved. Rimple's claw-lifter was ineffective. The spiked wheel used by Armer showed little promise, although later a modification of this principle was used successfully by others. The Scott-Viner machine was unacceptable for California conditions. The Tramontini vibrator-lifter did not seem to possess reliable operating features which led to its eventual abandonment, perhaps prematurely. During this period, war clouds were forming and ready to break, and the pressure for some kind of labor-saving equipment for harvesting beets was acutely urgent. Loaders came into use; cross-conveyor harvesters and disk toppers were tried out with some satisfaction. Among those used were the Alvos, Rappetti, Hansen, Hunt Bros. and Zuckerman. Armer worked on the sorting-table principle, and Armer and Bainer together developed a two-row, topper-digger unit, with hand-sorting belts, and with ultimate delivery of beets direct to trucks. All of these units were cumbersome and relatively expensive to operate, even though some labor was saved. This pressure to do emergency work temporarily diverted the attention of most of the Station engineers from basic harvester research.

By 1942, the variable-cut topper developed by Powers was released for nonexclusive manufacture to three implement companies. Powers further perfected a leaf windrower to go with the topper and did preliminary work on a helical plow for lifting beets. He experimented with a chain-hook elevator to engage pretopped lifted beets in order to separate clods from the harvested beets. In spite of all of this pioneering, and basic work upon the part of Powers, the Station reports that year stated: "Our harvesting operations beyond topping have not reached a point of grower acceptance."

Industry was active during this period. The John Deere Company placed approximately 15 of its new harvesters in the field in 1942, and

programmed 100 for the following year. The Allis-Chalmers Manufacturing Company did experimental work in California, as did also the Sawtooth Company. The International Harvester Company adopted the disk-type of topper as developed earlier by Armer, and the Blackwelder Company was building harvester units after designs by Schmidt, Jongeneal and others. This year (1943), perhaps, marked the beginning of the successful commercialization of sugar beet harvesters.

Powers in his designs at the California Station was successfully using flat, thin knives for topping, as was also the John Deere Company. Disk-toppers were used successfully by International Harvester Company, and Marbeet (Blackwelder) was successful with machine topping, as was also Scott-Urschel. In September, 1944, Walker reported to the Advisory Committee of the United States Beet Sugar Association, in part as follows: "The work on harvesting machinery has continued with varying degrees of success . . . Machines now commercially available are operating in the field with sufficient success to keep them going; but these are also sufficiently faulty to create a desire for improvements. Topping, top recovery, and removals of roots without excessive dirt and breakage, appear to be the bottlenecks for a satisfactory product at the dumps. The problems of these commercial units have caused us (California Station) to direct our studies toward obtaining a better harvested product."

Powers continued diligently his efforts during the 1945-47 seasons in perfecting a single-row, tractor-mounted unit, using his own design of variable-cut topper, helical plow, chain-lift conveyor, cleaning elevator, and overhead bin. With this unit, he has been able in 1947 to obtain 96 percent recovery of beets with excellent topping quality and relatively low dirt tare in soils ranging from dry-hard to moist and sticky. Under good operating conditions for harvesting in flat planted, 20-inch row spaced beets, yielding 20 tons and upwards per acre, the rate of recovery has been 6 to 8 tons per hour. This unit represents 9 years of intensive development work at the California Station upon the part of J. B. Powers and associates, and it closely approaches the broad objectives set up for a functional unit by the project statement.

Thus, 16 years of technological effort, 9 years of which were conducted intensively under the handicaps of World War II, have yielded commendable achievements of benefit to the sugar beet industry. One must remember, however, that during these years of research, a sympathetic and anxious industry, functioning through its Advisory Committee, and an eager implement industry stood by at all times to lend aid and assistance to carry into immediate practice the findings of this research. To these faithful and helpful cooperators, much credit is due. It is believed by your speaker, however, that the research investment has been fully justified.

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## APPENDIX A

### Names and Title of Research Workers
### California Agricultural Experiment Station
### Sugar Beet Machinery Investigations 1931-1947

Armer, Austin A.....
Assoc. in the Exp. Sta., Univ. of Calif., Asst. Agri. Engr., USDA
Bainer, Roy.....Agri. Engr. in the Exp. Sta., Univ. of Calif.
Baker, Geo. A.....Asst. Statistician in the Exp. Sta., Univ. of Calif.
Barbee, C. E.....Assoc. in the Exp. Sta., Univ. of Calif.
Bice, Richard A.....Field Engineer (Colo.) Exp. Sta., Univ. of Calif.
Brooks, F. A.....Agri. Engr. in the Exp. Sta., Univ of Calif.
Hall, F. G.....Mechanician, Univ. of Calif.
Leach, Lyle.....Plant Pathologist in the Exp. Sta., Univ. of Calif.
Lewis, H. D.....Assoc. in the Exp. Sta., Univ. of Calif.
Lorenzen, Coby, Jr.....Asst. Agri. Engr. in the Exp. Sta , Univ. of Calif.
Lory, Fred, Jr.....Mechanician, Univ. of Calif.
McBirney, S. W.....Agri. Engr., U. S. Dept. of Agri.
Mervine, E. M.....Agri. Engr., U. S. Dept. of Agri.
Powers, J. B.....Assoc. Agri. Engr. in the Exp. Sta., Univ. of Calif.
Rimple, Ed.....Development Engineer, Exp. Sta., Univ. of Calif.
Robbins, W. W.....Botanist, Exp. Sta., Univ. of Calif.
Symens, P.....Mechanician, Univ. of Calif.
Tramontini, Vernon N.....Assoc. in the Exp. Sta., Univ. of Calif.
Walker, H. B.....Agri. Engr. in the Exp. Sta., Univ. of Calif.
Zimmerman, O. B.....Assoc. in the Exp. Sta., Univ. of Calif.

# Recent Developments in the Processing of Beet Sugar

R. H. COTTRELL[1]

UNDER the impetus of relatively high sugar prices and high volume of production on the one hand and high unit costs of labor and supplies on the other, our industry is experiencing a surge of new ideas in the processing of beet sugar. No one person can follow in detail all the current promising developments so my remarks must necessarily be limited to those newer developments with which I have had some experience or on which I have had reports.

Before describing equipment and processes, it will make the picture clearer to discuss economic pressures which are dictating the trend of technological developments.

For this purpose, I have prepared tables giving data which are indicative of changes in the economic picture during the past 10 years.

The largest single item of cost in the production of beet sugar is the amount paid farmers for beets. Table 1 shows these amounts per ton paid during the past 10 years for beets of 16.0 percent sugar content.

**Table 1**

| Year | Amount paid growers per ton of beets of 16.0 percent sugar content | Percentage |
|---|---|---|
| 1938-39 | $ 4.06 | 100.0 |
| 1939-40 | 3.94 | 97.0 |
| 1940-41 | 4.98 | 122.6 |
| 1941-42 | 6.16 | 151.7 |
| 1942-43 | 6.76 | 166.5 |
| 1943-44 | 6.84 | 168.5 |
| 1944-45 | 6.94 | 170.9 |
| 1945-46 | 6.42 | 158.1 |
| 1946-47 | 10.72 | 264.0 |
| 1947-48 | 11.72 | 288.7 |

These payments to farmers have been calculated by using the sliding scale in the beet purchase contracts and the actual net return from the sale of sugar by our Company in each respective year. You will note that cost of our raw material has risen 188.7 percent. The amount paid farmers for the raw material constitutes a very substantial part of the total cost of manufacture of sugar.

Table 2 shows the average hourly earnings of all factory employees during the campaign period for the respective campaigns. These earnings per hour are calculated by taking the total payroll and dividing by the total number of hours worked. Included in the group covered by this table are all employees from the classification of assistant superintendent to unskilled labor, inclusive.

[1]Vice President, The Amalgamated Sugar Company, Ogden, Utah

Table 2

| Campa'gn | Average hourly earnings of factory employees | Percentage |
|---|---|---|
| Avg. 1935-36 to 1938-39 | $ .4635 | 100.0 |
| 1939-40 | .5030 | 108.5 |
| 1940-41 | .5316 | 114.7 |
| 1941-42 | .6341 | 136.8 |
| 1942-43 | .7601 | 164.0 |
| 1943-44 | .8146 | 175.7 |
| 1944-45 | .8783 | 189.5 |
| 1945-46 | .9553 | 206.1 |
| 1946-47 | 1.0656 | 229.9 |
| 1947-48 | 1.2220 (estimated) | 263.6 |

The first figure ($ .4635) covers the years from 1935 to 1939 which are the years chosen by the Department of Labor as a base period for calculating the index of cost of living. Average hourly earnings of employees have increased 163.6 in the past 10 years. The current index of cost of living published by the Department of Labor is 166. Wages paid have outpaced rising cost of living by 100 points. These 100 points are available to employees for increased savings and improved standard of living.

Cost of fuel represents one of the largest items of factory operating expense. Table 3 shows the delivered cost of coal per ton at our Nyssa factory during the past 10 years.

Table 3

| Year | Delivered cost of coal per ton | Percentage |
|---|---|---|
| 1938-39 | $5.13 | 100.0 |
| 1939-40 | 4.99 | 97.2 |
| 1940-41 | 5.11 | 99.6 |
| 1941-42 | 5.18 | 101.0 |
| 1942-43 | 5.40 | 105.3 |
| 1943-44 | 6.06 | 118.1 |
| 1944-45 | 5.70 | 111.1 |
| 1945-46 | 6.16 | 120.1 |
| 1946-47 | 6.23 | 121.4 |
| 1947-48 | 8.20 (estimated) | 159.8 |

The increase in unit cost of coal delivered is 59.8 percent.

Sugar bags have contributed more than their share to rising costs and their use is not subject to managerial control. The use of low-cost types such as paper 100-pound units effects a substantial saving but the choice of container lies largely with the customer. To illustrate increased cost of containers a single type will be used as an example.

The price of a single container unit consisting of ten 10-pound cotton pockets with an 8-ounce burlap baler was $ .241 in 1938. Currently this same unit costs $1.005, an increase of 317.0 percent.

As a side light on current costs of containers, it may be said that our profits would disappear completely if the buyer elected to receive all sugar in the most expensive container now being used and if the current sugar sales differentials were continued.

Rising costs of the supply items shown in the preceding tables are typical of the trend of cost of all supplies.

While costs have risen, we have been enjoying an increase in the net return from the sale of sugar. Table 4 shows the net return per 100 pounds of sugar sold by Amalgamated in the past 10 years.

**Table 4**

| Year | Net return per 100 pounds sugar sold | Percentage |
|---|---|---|
| 1938-39 | $3.19 | 100.0 |
| 1939-40 | 3.13 | 98.1 |
| 1940-41 | 3.59 | 112.5 |
| 1941-42 | 4.24 | 132.9 |
| 1942-43 | 4.46 | 139.8 |
| 1943-44 | 4.50 | 141.1 |
| 1944-45 | 4.58 | 143.6 |
| 1945-46 | 4.28 | 134.2 |
| 1946-47 | 7.06 | 221.3 |
| 1947-48 | 7.25 (estimated) | 227.2 |

This increase in returns amounting to 127.2 percent may seem to offer an off-set to rising costs but the sliding scale beet purchase contract has compelled payment of a very substantial part of the higher income to farmers. Furthermore, there is evidence that the peak of sugar prices has been reached while there is no evidence of any end to the increase in costs.

Table 5 shows the percentage of the increase in returns which has been paid to farmers.

**Table 5**

| Year | Percentage of increased value of sugar in a ton of beets paid to farmers |
|---|---|
| 1938-39 | 0.0 |
| 1939-40 | —70.5 |
| 1940-41 | 84.4 |
| 1941-42 | 73.2 |
| 1942-43 | 77.8 |
| 1943-44 | 77.7 |
| 1944-45 | 75.8 |
| 1945-46 | 79.5 |
| 1946-47 | 62.9 |
| 1947-48 | 68.9 |

An explanation of this table is desirable. The figures have been calculated by assuming a normal yield of sugar in a non-Steffen factory from beets of 16.0 percent sugar. Applying the actual net returns for sugar for the respective years to this amount of sugar gives the value of refined sugar extractable from a ton of beets. Payments to farmers have been calculated from the net return and an assumed sugar content of 16.0 percent. As the value of a ton of beets has increased by reason of the increased net return, the farmer has received about 70 percent of the added value. In table 5 the value of sugar in the beets each subsequent year has been compared to the value in 1938-39 to arrive at the figures shown.

This leaves 30 percent of the added return for the processor and from this 30 percent he must meet his rising costs.

The question has been asked as to why we pay farmers 70 percent of the added value of a ton of beets as sugar prices increase. The farmer is not a beet raiser only, he can turn to other crops and if our volume is to be maintained he must receive a net profit on beets that is comparable to profit on other crops or he will discontinue growing beets. He will continue to grow beets so long as his returns are high or if his costs are lowered. Lowered farmer costs are the primary interest in most of the papers offered at these meetings.

To summarize: We are in a situation where we are enjoying added returns from the sale of our sugar but of the increase 70 percent is being paid to growers for beets. We are faced with rapidly rising hourly wage rates and increasing unit costs of all supplies. If current trends continue, our share of increasing returns will not meet rising costs and we will be squeezed between the two opposing factors. High volume of production which lowers fixed costs per bag and further economies in use of labor and materials may enable us to continue profitable operations.

Reduction in factory labor costs per-bag of sugar can be made by reducing the number of men employed and by increasing factory daily capacity. Economies in use of supplies can be realized by closer supervision of the process and by new developments in equipment and processes. The balance of this discussion will deal with some of these newer developments.

Our process has changed little since the industry was established in this country. The basic steps remain and improvement has been largely in perfection of the details of processing and in improved equipment to carry out the old process.

Present trends are toward continuously operated, automatically controlled stations. Continuous operation provides more uniform results and automatic controls eliminate labor and improve processing results.

With equipment already in use, it appears practical to centralize controls on a single panel and to control the diffuser, first carbonation, second carbonation, sulphur station and evaporators with one man. If the Ellernan kiln proves successful it may be controlled from the same center.

*Silver Continuous Diffuser.*—A description of this equipment is not necessary since most of you are familiar with its design. It was invented, designed and built by the Silver Engineering Works of Denver, Colorado. Amalgamated has three of these in operation currently, the one at Nyssa having been installed in 1946. Table 6 below summarizes the essential operating data on current operation of these diffusers.

Table 6

**Comparison of Standard Battery and Continuous Diffuser Operations**

| | Twin Falls | Nampa | Nyssa |
|---|---|---|---|
| Highest previous campaign average daily capacity in tons of beets—standard battery | 1,945 | 2,111 | 2,350 |
| Average tons beets sliced daily to date 1/1/48 with continuous diffuser[1] | 2,354 | 2,816 | 3,209 |
| Percent increase in capacity, diffuser over battery | 21.0 | 33.3 | 36.6 |
| Draft by sugar—battery | 148 | 153 | 160 |
| Draft by sugar—diffuser | 129 | 123 | 126 |
| Total sugar loss—battery | .29 | .32 | .24 |
| Total sugar loss[2]—diffuser | .21 | .16 | .20 |
| Number of men employed—battery | 24 | 21 | 21 |
| Number of men employed—diffuser | 3 | 3 | 3 |

[1]The data shown for diffuser operation for 1947-48 are to date averages for the following number of days of operation: Twin Falls, 93; Nampa, 106; Nyssa, 107.
[2]Sugar loss reported for the diffuser is the polarization of pulp.

On January 8, 1948, just 6 days ago, Nyssa established a new record slice of 3,447 tons of beets.

It is obvious that this equipment has made a valuable contribution toward reduction of man-hours of labor, toward reducing fuel consumption, reducing sugar loss and increasing factory capacity. In addition to the above measured savings are indirect savings arising from uniform high factory capacity.

The installed cost of a 21-cell diffuser, handling 3,200 tons of beets per day, has been of the order of $275,000.00.

A number of problems have developed in connection with diffuser operation. It is customary in our control of the diffuser to determine pH on raw juice and on juice from the 13th cell each hour. In addition, tests are made at less frequent intervals on the juice in all cells. Low pH values were found and were accompanied by high invert sugar and serious corrosion of equipment. Observation has lead to the belief that low pH is the result of growth of micro-organisms and control of such growth leads to improvement in pH.

During the first 12 hours of operation at Nyssa this year, juice from the 13th cell averaged 7.2 pH and diffusion juice 6.6. By the fourth day pH of cell 13 dropped to 5.0 and diffusion juice remained at 6.4. One test on cell 13 on the 5th day showed a low of 4.9 pH.

About 2 gallons of formaldehyde were added per hour to cell 13 by a continuous feed from a constant level syphon. The pH rose to 5.9 and 6.0. Subsequently this dosage of formaldehyde became ineffective. Tests were taken on juice from all cells and at the point of lowest pH massive doses of formaldehyde were administered in one shot. These doses at times exceeded 3 gallons. This corrected pH for a time but became ineffective and massive doses were added at the point of minimum pH followed by the same dosage to a series of cells on either side of the point of minimum pH. It became evident that formaldehyde alone was not a sufficient corrective.

The Great Western Sugar Company reported that control of pH had been effected by admitting steam to the domes of cells 8 to 13. This was tried with considerable improvement in pH conditions.

After some experimenting with chlorination of battery supply water and neutralizing of the diffuser juices with lime or soda, we are now adding formaldehyde at the rate of 2 gallons per hour to cell 13 and maintaining a temperature of battery supply at 68° C. or higher. This is not to be considered a final solution of the problem but at the moment is maintaining pH at 6.0 or higher throughout the diffuser.

Corrosion of diffuser parts has been serious. After 250 days of diffuser operation at Nyssa it has been necessary to replace 25 perforated trays. It may be necessary to replace all original trays before the next campaign. Test plates of steel hung in the juice channels lost 20 percent of their weight in less than 100 days.

When pH values are maintained above 6.0, a dark scale forms on all surfaces which appears to afford considerable protection.

Presence of dissolved oxygen in the juices as well as low pH should not be overlooked as a possible cause of corrosion. To reduce oxygen content we keep all ports on the diffuser closed. Oxygen content drops rapidly after closing ports.

Since the gases remaining in the cell domes may be combustible, all flames and arcs should be kept away from cell openings.

From experience with the diffuser during the past campaign, I believe it will eventually replace the standard battery in many factories.

*Ion Exchange.*—Since several papers are being offered on this subject, it will not be discussed here except to say that it offers the most promising development and most radical departure from the standard process made available to the industry for many years. I believe it will eventually replace all standard process operations from the diffuser to the evaporators. In addition to higher recovery of sugar at lower cost it will stimulate a whole new field of by-product recovery.

*Fuel Economy.*—Consumption of fuel is subject to a greater degree of control than any other major item of supply cost. Since it is also one of the largest costs and unit fuel costs are rising so rapidly it offers a promising subject for investigation. The subject logically divides itself into steam economy and boiler house efficiency.

*Steam Economy.*—Without remodeling equipment already installed, substantial savings in steam consumption can be made by careful attention to station operation; low battery draft; reduction of wash water on carbonation presses; avoidance of excessive use of steam through open nozzles in open juice boilers and Steffen waste heaters.

With vacuum drum filters after first carbonation, water dilution may be as low as 5 percent on beets, a little carelessness and it increases to 10 percent. For each 2.5 to 3.0 percent of dilution 1.0 percent of steam on beets is required for evaporation.

Higher yields from pans, use of higher density syrups and other sound practices can yield high returns in steam economy. These are all recognized standard practices.

With standard non-Steffen equipment processing normal beets of around 16.0 percent sugar, we can expect steam consumption in the range of 80.0 to 90.0 percent on beets.

The new diffuser will reduce steam consumption 10 to 15 percent on beets, depending on the conditions of the steam balance.

Steam economy has probably advanced farther in Europe than in the United States. Only relatively few factories in this country have found the European methods justified by savings in fuel costs. Now the unit cost of fuel demands a review of our practices.

Starting with high-pressure boilers (300 psi or over) the steam can be put through a turbo-generator leaving the exhaust at 35 psi. At this pressure it seems advisable to employ long tube vertical evaporators in which retention time is of the order of 5 minutes in each body. If all classes of pans, including white, are boiled on vapor sufficient steam will enter the first effect to accomplish concentration of thin juice to normal thick juice in three effects. Because there must be fluctuations in pan demand for vapor resulting at times in lowered input of steam to the first effect a fourth effect would be required for these intervals.

To use vapor for white pan boiling requires a calandria type pan. The ribbon coil pan seems to have some advantages over standard design. Latest developments tend toward mechanical circulation.

At this point, it may be well to total the steam savings that are possible in a modern efficiently operated plant over the plant that has not taken advantage of new equipment and methods.

The continuous diffuser can save at least 10 percent steam on beets. High pressure evaporators with the necessary remodeling of pans can save another 10 percent. Efficient beet and sugar end management can each save another 5 percent. The total saving will then be some 30 percent on beets.

With present knowledge the practical lower limit for steam consumption is from 55 to 60 percent on beets.

*Boiler House Efficiency.*—(Since none of the factories of our Company can use gas or fuel oil, my remarks will be limited to coal fired equipment.)

The trend in modern boiler construction is toward higher pressures, the use of pulverized coal in place of firing coal on a grate, and the use of air preheaters.

For the present, there seems to be little justification for going above 300 psi working pressure. With modern turbine design acceptable water rates are realized at these pressures and as there is need for about 50 percent process steam on beets we must add 10 to 15 percent low pressure make-up to the exhaust line even for turbine back pressures of 35 psi.

Below 400 psi it is difficult or impossible to exceed a boiler efficiency of 80 without an air preheater. With an air preheater efficiencies of over 85 are reached.

Current coal prices justify air preheater and induced and forced draft fans.

The trend is toward fewer boilers. Former practice provided from 5 to 12 or even more units. The limit in reduction has been reached at our Twin Falls factory where one boiler serves the factory. With one or two units it is a relatively simple matter to employ automatic, registering controls. We have found Bailey controls reliable and they require little maintenance.

Probably a substantial number of the factories in this country operate with steam consumption at a level of 90 percent on beets and a boiler house efficiency of 70 percent.

A factory cutting 2,400 tons of beets per day and having 100 days of campaign will spend $215,000 for coal under the above conditions. Compare this with a factory designed to consume 60 percent steam on beets and with a boiler house efficiency of 85 percent. This plant would spend $118,500 in a similar campaign. The saving is $97,000 per campaign or $970.00 per day. As fuel costs go higher these differences will increase.

*Evaporator Control.*—Evaporator controls developed by the Taylor Instrument Company have now been in use long enough to be evaluated. They are successful in eliminating the evaporator operator and in giving more efficient operation than manual control. Brix of thick juice is more uniform. More nearly constant pressures are maintained on vapors used for heating and pan boiling. Electric eye foam controls have been installed on each body at our plants to avoid the need of continuous supervision. Elimination of the evaporator operator on three shifts results in a saving of $3,456 in a campaign of 120 days at current wage rates. Indirect savings are difficult to estimate. The equipment was installed complete with foam control for about $11,000 per factory.

*First Carbonation Control.*—Work on this control has not progressed to a point where the operator can be eliminated. However, some encouraging results have been obtained.

*Second Carbonation Control.*—For the past two campaigns we have used fully automatic control on second carbonation and have obtained better results than with manual control. The Second Carb station control consists of a Beckman No. 9000 Model R pH Meter connected to a Bristol pH Recording Pyromaster Reset Recorder Controller Model K R 531 which in turn is connected to an air operated Diaphragm Valve on the gas line. Installation of these instruments was made in such a manner that the sample to the Beckman is taken from a point a very short distance above and somewhat to one side of the gas manifold in order to get a sample free of gas and with a minimum of lag.

The Beckman Model R pH Meter sells for about $524.50 complete with the necessary electrode assembly. The Bristol Controller with 12-inch chart sells at approximately $470. A good diaphragm operated valve for a 4-inch gas inlet sells for approximately $167.

*Sulphur Station.*—For the past two campaigns we have used automatic controls on the sulphur station with satisfactory results. I realize this has been long established in factories where liquid $SO_2$ is available at reasonable cost. The controls referred to here apply to sulphur stations equipped to burn elemental sulphur in Glen Falls type stove. The stoves are manually fired and all other operations are fully automatic.

The sulphur station is operated in the same manner as the second carbonation except that for opening and closing a gas valve the Bristol Controller operates a Bristol No. 12 Syncro-Lever Motor which is connected to the damper on the sulphur stove. Care must be exercised in determining the point of sample connection to the sulphur tower in order to get as quick a sample as possible to the Beckman. Cost of the sulphur station equipment is the same as second carbonation equipment except for the Syncro-Lever Motor, which sells for $95 as against the gas valve used on carbonation at $170.

*Factory Bulk Sugar Storage.*—This is not a recent development but is not yet in general use largely because of high initial investment. It has many advantages. Sugar need be sacked on only the day shift thus avoiding the necessity of trained supervision and skilled stackers on two shifts. It is not necessary to anticipate buyers' requirements for sugar packages of different sizes and types. Within a reasonable range of grain sizes, sugar can be screened at time of sale into a number of grades from the regular run in bulk storage. Loss in broken containers is greatly reduced. Initial cost of bulk storage currently runs from $ .50 to $ .55 per 100 pounds of sugar. Our bins have been installed by J. T. McDowell and Sons, Denver, Colorado.

*Quality of Sugar.*—In recent years the three boiling system has been adopted almost universally in American beet sugar factories. This has resulted in higher purity white pans. The use of high speed, automatically controlled centrifugals together with fillmass of higher purity has brought about improvements in the quality of sugar. For analyses of representative sugars from our industry the annual report of the Bureau of Agricultural and Industrial Chemistry of the United States Department of Agriculture may be consulted.

Bottlers and canners have established minimum standards governing contamination of sugar by the following groups of organisms: flat sours, thermophiles, positive anaerobes not producing $H_2S$, bacteria developing at 37° C., molds and yeasts

Exceptional care is required to meet these standards.

A preliminary survey of the process by our bacteriologist indicated that initial contamination of juices was greatly reduced by high alkalinity

and temperatures in first carbonation. Subsequent contamination occurred where juice was exposed to the atmosphere. Many organisms were killed in the white pan but from there on contamination might recur.

It is now our practice to spray standard liquor presses and the whole area around high melter, white mixers, white machines and all equipment from these machines to the sacking station, with roccal or hyamine solution.

Condensate on the sides of wet sugar scrolls and elevator and in pan storage tanks are potent sources of contamination. These surfaces where exposed are subjected to rays from sterilamps. Chutes and scrolls under the white machines are completely enclosed and air is forced through a radiator and then through a bank of sterilamps and through this area to dry the condensate and reduce the growth of organisms. The whole environment of the final sugar must be kept as sterile as practical conditions permit.

In one of our plants all air going to the granulator is passed through a series of screens, then through glass wool filters and then through a Westinghouse precipitron. The precipitron removes suspended particles as small as those in cigarette smoke. After this treatment the air passes through the standard radiator to the granulator.

If all precautions against contamination are faithfully followed, the sugar may approach sterility.

*Thick Juice Filtration.*—Plate and frame presses seem to me to be an exceedingly crude method for filtering, involving as they do high labor costs and high consumption of filter cloth. Favorable reports have been received on Niagra filters but I have no direct observations to report.

*Lime Kiln.*—We feel that we are approaching practical limits on lime kiln capacity. In some cases passage of the rock through the kiln occurs in less than 30 hours requiring a rock so small that quarry costs are increased beyond the normal cost increase. We are investigating the Ellernan kiln which seems to have advantages over the standard shaft type where small-size spalls are available. We expect to make one installation for the 1948 campaign.

*Cutters.*—It has been assumed by some operators that the new continuous diffuser does not require uniform clean-cut cossettes. In my opinion the same care should be exercised on knives and cutters where the diffuser is used as for the standard battery. The Ogden Iron Works cutter with chrome plated wearing surfaces has many refinements that are of practical value. Chrome plating of wearing surfaces prolongs the life of parts and reduces distortion of equipment resulting from wear in long campaigns.

*Pumps.*—Continued high capacity operations during campaign are particularly dependent on pumps. We have found the recently designed Bingham pumps manufactured by the Bingham Pump Company of Portland, Oregon, highly satisfactory. Each pump is designed for its individual service. The foam-liquid juice pump separates foam, entrained air or

gases from the liquid entering the pump suction and transports the juice without pulsation. The Bingham beet pump elevates beets and water from the flume replacing beet wheels and elevators ahead of the washer. The Bingham pulp hog has eliminated many of the troubles found with most pulp pumps. We have found these pumps long lasting and relatively trouble free.

*Minor Improvements.*—A whole new field of minor improvements is available to the processor. To mention only a few, we have improved metallic alloys and plastics which may be used in special service to reduce abrasive wear and corrosion. New welding equipment and techniques are available. We are trying new plastic filter cloths which appear far superior to the old textiles.

In this discussion specific pieces of equipment have been mentioned. I would like to emphasize that the list is not exclusive. Those mentioned are some of the newer developments that have proved useful. There is a whole field of standard equipment produced by well-established firms that cannot be listed here.

# The Utilization of Sugar Beet By-Products for Livestock Feeding

E. J. Maynard[1]

THE SUGAR beet by-products—beet tops, wet and dried beet pulp and beet molasses—have been used extensively as livestock feeds for many years with little change in the methods of handling and feeding them.

Because of their special adaptability for this purpose, they have exerted a profound influence on the increased volume production of meat and milk in those areas where sugar beets have been grown. This has been due to their succulence and high palatability, to their ability to improve grain and hay rations, and particularly to their very low comparative costs in terms of the actual grain and hay that they have replaced in livestock rations. However, largely because of the wasteful methods in handling them, the fact remains that even today there still exists a wider difference between their actual feeding value, and the lower value attributed to them by many beet growers, than exists for other livestock feeds produced on the farm.

While difficulties encountered in handling and feeding some of these by-products are recognized, a clear conception of their actual feed-replacement value and a better appreciation for the contribution they can make to a sound feeding and farming program should present a challenge to technologists and processors alike to develop more efficient methods for their conservation, and to stimulate and encourage livestock-feeding operations on more beet farms through continued demonstration of their ability to improve rations and to materially reduce livestock-feeding costs.

There is an urgent need today for a more widespread livestock-feeding program on the beet farms of America. There are still too many large centralized feeding operations in close proximity to sugar beet factories, with far too many farms in the outlying beet-producing territory where little or no livestock is being fed. It is time to take stock of this situation and to develop a definite program to obtain a wider distribution of these beet by-products in order to make livestock feeding more attractive on these farms and to insure production of the fertility needed for higher acre yields of beets.

The drying of wet beet pulp has proved an efficient step toward the decentralizing of livestock feeding in beet-growing areas, although this development has also resulted in the marketing of some of this product outside of beet-growing territory. But the fact remains that many beet growers still need information and guidance in developing more efficient methods for handling and feeding their by-products in order to realize and fully appreciate the value of their sugar beet crop as a whole.

[1]General Livestock Consultant, The Great Western Sugar Company, Denver, Colorado

There is a fund of dependable experimental evidence already available to indicate the feeding value of these by-products as they have been handled and fed in the past; evidence that has provided ample proof to indicate that the by-products alone from the sugar beet crop, if given only reasonable care on the farm, can provide as much net feeding value for livestock as an entire crop of corn, barley or alfalfa hay grown on comparable acreage. But there are opportunities today for further studies that can point the way toward even more efficient methods of harvest and conservation, and even greater values for the beet by-products as livestock feed

This year, the American Society of Sugar Beet Technologists has included an agronomy subsection for a more detailed consideration of these beet by-products. Such a move appears particularly important at this time when the rapid transition to the mechanized harvest of the beet crop is creating new problems concerning the harvesting and processing of the beet-top crop, and when dependable data are urgently needed for the further refinement of various types of beet harvesters with regards to methods for salvaging beet tops and protecting them for use as livestock feed. Such problems include for instance, the question as to whether beet tops should be beaten off and disintegrated, to be left lying on the ground exposed to the elements until such time as they may be plowed under, or whether the tops and crowns can be used to better advantage in the long run if they are properly conserved and used as a farm feed for livestock.

Problems such as these require a knowledge of the feeding value of tops as they are used today, as well as more information to show their potential value with the new and more efficient methods now available for their mechanical harvest, and for various methods of processing and storage to better conserve their nutrient values.

Feeding experiments that have been designed to answer some of these questions are already in progress. In one test with cattle, a comparison is being made with ensiled fresh green tops, ensiled wilted tops, and field-cured dried tops.

Another feeding test with lambs is comparing the feeding value of ensiled fresh green tops, fresh green tops ensiled with phosphoric acid, ensiled wilted tops, dehydrated tops and crowns, dehydrated leaves and petioles, and field-cured dried tops.

But we are concerned today, primarily, with the present utilization of these by-products and the values they have already shown as livestock feeds.

Many livestock-feeding tests conducted at various state and federal experiment stations during past years have established some simple basic facts relating to feeding practices that have resulted in more efficient returns from beet by-products than were formerly secured. It may be well to mention the most important of these before discussing the feed-replacement values of these by-products.

It is now generally recognized that livestock rations that are high in beet by-products and that contain little or no grain may give relatively poor results because of a deficiency in phosphorus, due to the low-phosphorus content of the by-products. This situation can be remedied by feeding a phosphorus supplement such as bone meal or some high-phosphorus feed such as wheat bran or one of the protein concentrates. Equally good results are secured from organic or inorganic phosphorus and, consequently, this phosphorus deficiency may not occur later in the feeding operation when more grain is included in the ration. Many experienced feeders today carefully check the phosphorus content of their beet by-product rations, realizing that a lack of phosphorus may be just as serious as insufficient protein in securing most efficient results. It is now a well-recognized fact, too, that in order to secure the full feeding value from dried beet pulp, it should never be fed as a "lone" carbohydrate in livestock rations, but should always be fed mixed with grain or in conjunction with such feeds as corn silage, corn fodder, mill feeds or protein concentrates. Fed alone, it has only three-fourths of a grain value. Fed in these combinations it is fully equal to grain.

Beet tops are of primary importance as a livestock feed, for they are available on every beet farm and constitute a very palatable farm feed that is high in protein of excellent quality and rich in both minerals and essential vitamins. Beet tops today are fed to beef cattle, dairy cattle, sheep and swine, and represent more than 50 percent of the total livestock feeding value of the entire by-products derived from the sugar beet. While their nutrient content would seem to class them as a substitute for legume roughage, many feeding tests have shown them to be valuable as a fattening feed as well.

While feeding values have been rather definitely established for such standard feeds as corn, barley, hay, dried beet pulp and even wet beet pulp as they are harvested or processed at present, it has been more difficult to determine the actual feed-replacement value of beet tops as they are handled and fed today, due to the wide variation in present methods of handling them. The fact is clearly demonstrated by an extensive survey made by the Beet Sugar Development Foundation in 1946[2] which covered some 67 percent of the total beet acreage harvested in the United States and Canada. This survey indicates that nearly 50 percent of the tops from all beets harvested were left lying out in the field without being windrowed or piled, that only 29 percent were field-cured and dried in small piles, while only 1 percent were ensiled. Although it is evident that a portion of those tops that received no care at harvest time were eventually pastured by livestock, it is evident too that there would be an unaccountable loss of nutrients from any feed harvested and handled in such manner. However, in view of the fact that many of these beet tops are pastured by cattle and sheep while they are still green, it would seem reasonable to use the field-

[2]Beet Sugar Development Foundation Report, Vol. III, No. 7

cured dried-top replacement value in attempting to determine the present average feeding value of beet tops as a whole.

In 1945, I published a general summary of livestock feeding tests with the beet by-products which had been conducted at the various western state and federal experiment stations throughout the years. This summary included all experimental data available where each beet by-product had been fed in a ration with grain and alfalfa hay, and where its feed replacement value in terms of the actual pounds of grain and hay that it replaced had been determined on the basis of unit feed required and unit gains secured on fattening livestock, by comparison with a check lot of livestock which had been fed a ration of grain and hay alone in the same experiment. The summary included 27 feeding tests with field-cured dried beet tops that had been handled according to customary methods of harvest on the farm; 29 feeding tests with wet beet pulp of approximately 11 percent dry matter content, and 42 feeding tests with dried beet pulp.

Those familiar with the feeding of the sugar beet by-products as supplements to a grain and hay ration will recognize the fact that they replace *both* grain and hay in producing equal gains in weight on livestock, and that, consequently, their feed-replacement value will be shown by the amounts of both grain and hay that they replaced in these experiments.

A weighted average of the results of all these tests showed that the field-cured dried tops from a ton of beets (approximately 200 pounds of dry substance) replaced 46 pounds of corn plus 150 pounds of alfalfa hay; that the wet beet pulp produced from a ton of beets (approximately 560 pounds of 11 percent dry matter pulp) replaced 41.6 pounds of corn plus 99.5 pounds of alfalfa; that the dried beet pulp produced from a ton of beets (approximately 90 pounds of 90 percent dry matter pulp) replaced 80.2 pounds of corn plus 37.6 pounds of alfalfa hay, and that the Steffens discard molasses produced from a ton of beets (approximately 35.4 pounds) replaced 20.1 pounds of corn plus 26 pounds of alfalfa hay.

These experiments showed, then, that in the aggregate, the by-products from a ton of sugar beets replaced 107.7 pounds of corn plus 275.5 pounds of alfalfa hay on a wet-pulp production basis, or 146.3 pounds of corn plus 213.6 pounds of alfalfa hay on a dry-pulp production basis.

It is interesting to note what these actual feed-replacement values show field-cured dried beet tops to be worth as livestock feed with the present fantastically high prices of other feeds. With corn at $4.50 per hundredweight, and alfalfa hay at $20 per ton, the tops produced from a ton of sugar beets would have a feed-replacement value of $3.57. Each ton of wet beet pulp replacing 148.6 pounds of corn plus 355.4 pounds of alfalfa hay would be worth $10.24. Each ton of dried beet pulp replacing 1,782.2 pounds of corn plus 835.6 pounds of alfalfa hay would be worth $88.56 bulk basis, and each ton of molasses replacing 1,136 pounds of corn plus 1,469 pounds of alfalfa would be worth $65.81.

These figures based on the present market prices of corn and alfalfa may surprise you. I have burdened you with these details for two reasons. First, to attempt to demonstrate that the replacement feed value of the beet by-products are not yet clearly or widely enough established to be accepted by many beet growers who could benefit accordingly, and then to afford an opportunity to compare these authentic feed-replacement values to the current market prices of these by-products to indicate the contribution they are making to more efficient livestock-feeding operations on the farm, and the advantages they provide to those beet growers who fully appreciate their value and who conserve and use them to best advantage.

While any widespread survey and study of many feeding operations must naturally be expected to represent an approximation of replacement feed values, it should be recognized that the improvements in beet by-product rations during recent years would appear to make these general findings conservative. In these feeding tests, field-cured dried tops, even with the nutrient losses sustained with this method of harvesting, have shown feed-replacement values equal to the digestible nutrients they have been shown to contain, while wet pulp, dried pulp and molasses have shown even higher values than those attributed to them by this method of evaluation. This can be accounted for by the well-recognized fact that the beet by-products have a common tendency to keep livestock on feed and gaining steadily by adding palatability to the ration and by eliminating indigestion and bloat, a rather common occurrence that tends to reduce average daily gains where the small grains and hay are used alone.

The magnitude and feed-replacement value of this sugar beet by-product crop presents today a real opportunity for the development of a universal livestock-feeding program on all beet farms; a program that will fit in well with the national plan to increase fertility of the soil, and with benefits to beet grower and processor alike.

Consider, for instance, that this past year some 12¼ million tons of sugar beets produced in the United States have provided some 1¼ million tons of dry matter in beet tops, 1,300,000 tons of wet beet pulp, 318,000 tons of dried beet pulp, and 217,000 tons of molasses—a supply of livestock feed that, according to available evidence, is capable of replacing some 28 million bushels of corn and nearly 1½ million tons of alfalfa hay.

Such a crop, capable of building the fertility and improving the soil on many thousand beet farms, can well justify any efforts expended to better establish its value in the minds of those it can benefit most.

# Seed Germination and Preparation

# Chemical Loosening of Seed Caps in Relation to Germination of Sugar Beet Seed

C. F. Lackey[1]

The object of these studies was to find an efficient chemical method for loosening the caps of the sugar beet seedball and in that way hasten and increase seed germination.

The seed caps loosen along a definite line of cleavage, making a clean, smooth break. Figure 1-A shows a seed cap in place before germination of seed with remnants of stigmatic lobes and 1-B underside of a seed cap that shows a definite abscession layer where it joins the seed ball.

There are two materials in plant tissue that can act as cementing substances. These are pectic substances and hemicelluloses. Pectic substances occur in unlignified cell walls in the middle lamella and in the cellulose containing lamellae. They are abundant in apples and citrus fruits and in certain fleshy roots, as carrot and turnip. They are dissolved by some acids but not by alkalies. These pectic substances are readily stained red by use of the ruthenium red method. The hemicelluloses are of two kinds: (1) skeleton hemicelluloses which occur chiefly in woody cell walls and in seed coats, (2) storage or reserve hemicelluloses found mostly in the cell walls of endosperm and very young bast fibers. They are dissolved by weak NaOH or dilute mineral acids such as HCl or $H_2SO_4$, but not organic acids such as acetic acid. They are not stained by the ruthenium red method.

Sugar beet seedballs in different stages of development were sectioned and given the Maule test which is specific for lignin. These tests revealed that there is a progressive lignification of the seed coat, inner walls of the seed locule, and several cell layers of the seed cap and surrounding walls of the seedball locules.

Seed were treated with 4-percent NaOH for 2 to 24 hours. The seed caps were loosened to such an extent by this treatment that they could be shaken loose from the seedball. This indicated that some form of hemicellulose was the cementing substance. Treatments with 10-percent trisodium phosphate, 3-percent HCl and 3-percent $H_2SO_4$ showed loosening of caps and increased germination. Glacial acetic acid had no effect on the seed caps. Sodium hypochlorite in 1-to-4 dilution of the commercial 5.25-percent solution loosened caps a little but depressed germination, as did the 4-percent NaOH. The two dilute acids, 3-percent HCl and 3-percent $H_2SO_4$, loosened caps but not as much so as 4-percent NaOH. However, these acids increased and hastened seed germination.

It was observed how readily the seed cap loosens when a beet seed within starts to germinate. It was thought that possibly the process of

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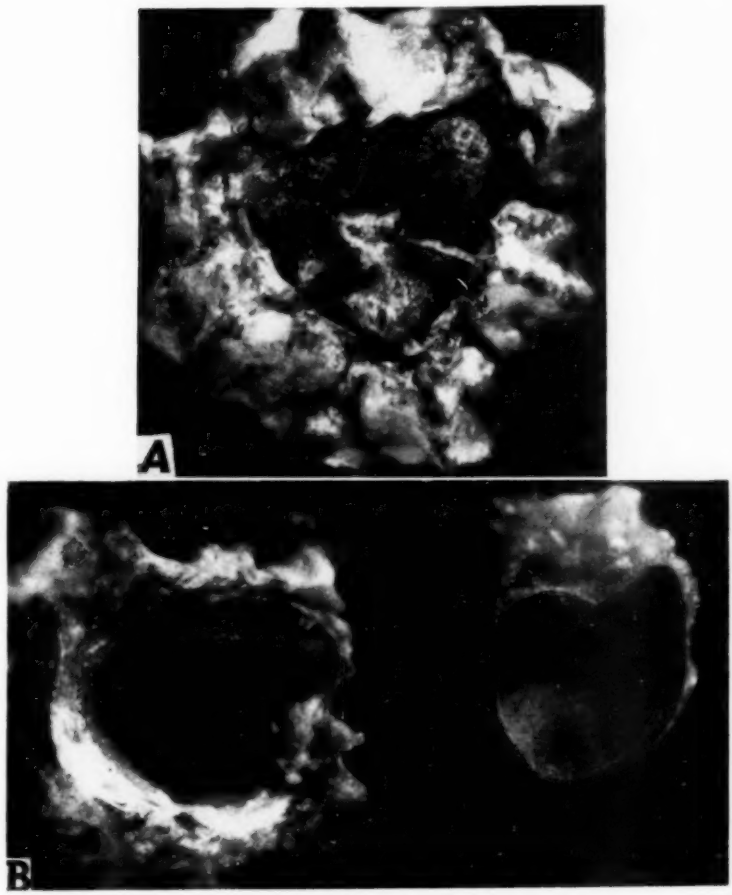


Figure 1.—Showing upper and under side of sugar beet seed cap and seedball. A. Seed cap on seedball before germination with remnants of stigmatic lobes visible in center of cap; B. Early stage germination showing seed with radicle having lifted edge of cap, and cap removed to show under side with its smooth edge where it separated from seedball by means of a clean-cut abscission layer.

germination might release some compound or enzyme which dissolves the hemicelluloses and loosens the seed caps. Therefore, to test the effect of the chemical treatments alone it was necessary to kill the seed. This was done by soaking the seed in 95-percent alcohol for 48 hours and also by treating seed 5 hours at 100° C. After this treatment some of the seed were soaked in 4-percent NaOH and 3-percent HCl and the check lots in distilled water. The caps of the seed treated with NaOH and HCl were loosened but the checks in distilled water remained unaffected.

Germination tests were made with seed treated with each chemical which did not depress germination. The results of these tests by the blotter method with 3 percent HCl, 3 percent $H_2SO_4$, and 10 percent trisodium phosphate are shown in table 1. The HCl and $H_2SO_4$ treatments gave practically the same average germination, 93.6 percent for HCl, 94.2 percent for $H_2SO_4$, as compared with 84.6 percent for the distilled water checks, increases of more than 10 percent. The 10-percent trisodium phosphate gave 92.8 percent germination for a ¼-hour treatment, as compared with 87.9 percent for distilled water checks.

Table 2 shows the results of treating a lot of exceptionally hard and some ordinary or relatively soft sugar beet seed with 3-percent HCl for 2 hours with checks in distilled water. This treatment gave an increase of germination of 11.6 percent over the checks with the hard seed which were slower and more difficult to germinate than the soft seed. The softer seed showed an increase of only 5.5 percent as a result of the HCl treatment. Some lots of both kinds of seed treated with HCl were dried for 2 to 4 days before testing. These gave as good germination as those that were tested while wet.

**Table 1.**—Effects of seed treatments on the germination of sugar beet seed, washed for 2 hours after treatment. Readings made after 96 hours. Each test represents the average of four 100-seed replications.

| | TREATMENTS | | | | |
|---|---|---|---|---|---|
| | 3% HCl 2 hours Pct. | 3% $H_2SO_4$ 2 hours Pct. | (Checks) Distilled water, 2 hours Pct. | 10% Trisodium Phosphate, ¼ hr. Pct. | (Checks) Distilled water Pct. |
| | 96.9 | 95.2 | 84.3 | 93.9 | 82.5 |
| | 95.6 | 93.6 | 93.8 | 90.4 | 87.7 |
| | 91.9 | 93.5 | 76.1 | 94.1 | 93.2 |
| | 94.7 | 93.3 | 86.4 | 94.9 | 85.5 |
| | 92.1 | 94.9 | 83.9 | 88.1 | 93.3 |
| | 95.6 | 96.2 | 81.4 | 94.4 | 89.5 |
| | 92.1 | 93.9 | 83.9 | 93.3 | 88.0 |
| | 90.3 | 96.2 | 86.1 | 92.1 | 84.3 |
| | 93.3 | 97.5 | 85.6 | 93.7 | 87.4 |
| Average | 93.6 | 94.2 | 84.6 | 92.8 | 87.9 |

**Table 2.**—Effects on germination of treating hard and soft sugar beet seed with 3-percent HCl for 2 hours and washing 2 hours in running water, compared with checks treated with distilled water 4 hours the same way. Each figure represents the results with 100 seed.

| | HARD SEED | | SOFT SEED | |
|---|---|---|---|---|
| Test No. | Germination with 3% HCl Pct. | Germination Distilled water checks Pct. | Germination with 3% HCl Pct. | Germination Distilled water checks Pct. |
| 1 | 96 | 89 | 95 | 90 |
| 2 | 92 | 88 | 96 | 92 |
| 3 | 92 | 74 | 94 | 87 |
| 4 | 83 | 73 | 96 | 91 |
| 5 | 96 | 86 | 96 | 89 |
| 6 | 85 | 74 | 97 | 92 |
| 7 | 94 | 85 | 96 | 92 |
| 8 | 92 | 88 | 95 | 91 |
| 9 | 88 | 78 | 96 | 88 |
| 10 | 94 | 85 | 93 | 89 |
| 11 | 81 | 72 | -- | -- |
| 12 | 90 | 82 | -- | -- |
| Averages | 90.4 | 81.0 | 95.4 | 90.4 |

The 3-percent HCl treatment hastened germination in soil also. Tests were made with the hard seed treated as in table 2 except the seed were planted in soil flats in alternate rows. In 16 replications the HCl-treated seed showed an increased germination of 8.9 percent and 25 to 30-percent faster emergence 7 to 10 days after planting than the checks. Thus, the soil tests which gave 8.9 percent increase in germination showed a fairly close correlation with the blotter tests which showed an increase in germination of 11.6 percent.

## Summary

Microchemical and other chemical tests indicated hemicellulose is the cementing substance holding seed caps in place on sugar beet seedballs.

The cementing substance was dissolved and the seed caps were loosened when sugar beet seed were treated with 4-percent sodium hydroxide for 2 to 24 hours. Commercial sodium hypochlorite, 5.25-percent strength, in a 1-to-4 dilution, also loosened seed caps somewhat. Both these alkaline solutions depressed germination.

A 10-percent solution of trisodium phosphate in a ¼-hour treatment loosened caps and gave 92.8-percent germination as compared with 87.9 percent in the checks treated with distilled water.

Treatments with 3-percent hydrochloric and 3-percent sulphuric acids hastened the rate and increased the percentage germination of sugar beet seed, as an average, more than 10 percent over checks treated with distilled water.

One lot of exceptionally hard beet seed and some ordinary, relatively soft sugar beet seed were treated with 3-percent HCl for 2 hours. This treatment gave an increase in germination of 11.6 percent for the hard seed and 5.5 percent increase for the soft seed over the checks. Some of the hard seed were treated with 3-percent HCl for 2 hours, washed 2 hours and planted in soil in flats. In 16 replications germination was increased 8.9 percent and emergence of seedlings hastened 25 to 30 percent as compared with distilled-water checks in 7 to 10 days after planting.

Some lots of seed treated with 3-percent HCl were dried 2 to 4 days before testing and showed as good germination as the lots tested wet.

# Field Compared with Blotter Germinations for Processed, Graded, Single- and Double-Germ Seed

H. L. Bush[1]

Mechanization of the sugar beet crop has given prominence to any method whereby a lower number of germs per seed unit might be obtained. This is necessary for accurate planting of small amounts of seed per acre. Segmenting or cracking the seedball, which may contain three or four germs, into portions containing mostly one or two germs results in a product which has generally been acceptable in accomplishing this end for the past several years. The process of pelleting these segments has also been tried. More recently the process of "burring" and "decorticating," which consists of rubbing the corky matter from the smaller seedballs, has been developed. Some processors are simply using the smaller grades of whole seed. The plant breeders are now developing varieties which will produce seedballs containing a lower number of germs.

## Materials and Methods

A test was designed in 1946[2] followed by a similar test in 1947 whereby various varieties consisting of different grades of segmented, decorticated, pelleted and whole seed were planted in the field so that the results could be directly compared with those obtained in the laboratory. The seed used was carefully graded with a slotted hand screen, except where otherwise noted, after which seedballs were counted out according to the scheme employed in the regular laboratory analysis. Two samples of 100-seed units each were germinated in the laboratory with the other samples being taken to the field.

The 1946 field test was planted with 100-seed units being distributed in each plot by hand at an accurate 6-inch spacing. There were three dates of planting. The first and second dates consisted of 2 replicates, with 8 replicates for the third date. The planting dates were April 22, May 10, and May 20, respectively. The first planting in 1947, consisting of 5 replicates of 100-seed units for each plot, was made with a John Deere No. 66 Planter geared to deposit one seed unit every 6 inches, the seed units being placed individually in the holes in the plates. Since there were some difficulties encountered by this method, the 2 successive plantings were made in the same manner as in 1946 with 4 replicates of 130-seed units for each plot being planted on each date. Plantings were made May 3, July 9, and August 22.

[1]Statistician-Agronomist, The Great Western Sugar Company Experiment Station, Longmont, Colorado.

[2]Brewbaker, H. E. and H. L. Bush. Graded whole vs. segmented, pelleted, and single- and double-germ seed in field germination tests. Proc. A. S. S. B. T. Regional Meeting of Eastern Slope and Intermountain, 1947, pp. 188-193.

In addition to this, in 1947, special tests of commercial decorticated, segmented, and whole seed were made by planting amounts of seed designed to give the same number of germinating units per foot of row. These tests were planted May 22, July 9, and August 22, the test for the first date involving only one variety, while seed from three varieties was used on the other two dates. The first planting consisted of 12 replicates, while for each of the two later dates 7 replicates were planted. This test was planted with a Planet Junior Hand Planter.

### Discussion of Results

Stands obtained covered a rather wide range in field germination since in 1946 the resulting stands were approximately 90, 70, and 30 percent of the potential for the three respective dates, while in 1947 corresponding values of approximately 70, 50, and 50 percent of the potential were obtained. Thus, these data can be considered as being obtained under such conditions as might be expected to prevail under a wide range of grower conditions.

The 1946 results are presented in table 1 and the 1947 results in table 2. The varieties included were all commercial lots except the double-germ strains, B333 and B401, and the single-germ strain, B402.

An increase in percentage of singles in the field over that indicated by the laboratory results amounted to about 12 percent as an average for all lots studied. This, along with a decrease in doubles or multiples, is a very important point to consider when processing seed.

Several commercial lots of whole seed, selected on the basis of varying number of apparent germs per seed, were included in the 1946 test, where the seed was used as it came from the commercial cleaning plant, screened over a 7/64-inch screen. While important differences exist between these lots of seed with regard to their range in production of singles and multiples, it is very interesting to note the rather high percentage of singles obtained in the field in all cases.

The double-germ varieties B333 and B401, while not appearing to give a higher percentage of potential than the other varieties, indicate the advantages that may be derived from using seed with few or no multiple germs. The very small grade (through 6/64-inch slotted, over 6/64-inch round) of B333 tested in 1946 resulted in a very poor germination, but B402, which resulted from screening B401 to this same grade, gave very satisfactory results indicating nearly all plants to be singles.

Segmented and whole seed performed quite similarly when comparable grades were considered. Direct comparisons between segmented and whole seed graded to either 7/64- to 9/64-inch or 7/64- to 10/64-inch for the variety GW85-46R in 1947 indicated that there were no essential differences between the field results for these two products. This conclusion is substantiated by studying the general performance of all grades of

**Table 1.**—Summarized Results. Germination Study, Longmont, 1946. Blotter germinations, averages for 2 samples of 100-seed units each. Field germinations, averages for 12 replicates of 100-seed units each.

| Variety | Treatment | Size[a] | Where germ. | Number of Seedlings per 100-Seed Units | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 or more | Total Seedlings | % singles | % germ. | % potential[b] |
| GW83 | Seg. | 7/9 | Blotter | 45.0 | 31.0 | 6.5 | 0.5 | 128.5 | 54.2 | 83.0 | --- |
| GW83 | Seg. | 7/10 | Blotter | 35.5 | 41.0 | 7.5 | 0.0 | 140.0 | 43.0 | 82.5 | --- |
| GW83 | Whole | Over 7 | Blotter | 28.0 | 38.5 | 14.5 | 4.0 | 164.5 | 32.9 | 85.0 | --- |
| GW83 | Seg. | 7/9 | Field | 19.7 | 11.4 | 1.4 | 0.1 | 47.1 | 60.4 | 32.6 | 36.7 |
| GW83 | Seg. | 7/10 | Field | 24.1 | 12.8 | 1.2 | 0.1 | 53.4 | 63.3 | 38.1 | 38.1 |
| GW83 | Whole | Over 7 | Field | 23.3 | 18.3 | 4.9 | 0.4 | 76.2 | 49.8 | 46.8 | 46.3 |
| GW49 | Whole | 7/8 | Blotter | 44.0 | 13.5 | 0.5 | 0.0 | 72.5 | 75.9 | 58.0 | --- |
| GW49 | Whole | 7/9 | Blotter | 46.5 | 21.0 | 1.0 | 0.0 | 91.5 | 67.9 | 68.5 | --- |
| GW49 | Whole | 8/9 | Blotter | 42.5 | 22.0 | 1.5 | 0.0 | 91.0 | 64.4 | 66.0 | --- |
| GW49 | Whole | 7/10 | Blotter | 46.0 | 26.5 | 1.0 | 0.0 | 102.0 | 62.6 | 73.5 | --- |
| GW49 | Whole | 9/10 | Blotter | 41.0 | 33.0 | 2.5 | 0.0 | 114.5 | 53.6 | 76.5 | --- |
| GW49 | Whole | 9/11 | Blotter | 35.5 | 39.5 | 4.5 | 0.0 | 128.0 | 44.7 | 79.5 | --- |
| GW49 | Whole | 10/11 | Blotter | 35.0 | 40.5 | 6.5 | 0.5 | 137.5 | 42.4 | 82.5 | --- |
| GW49 | Whole | Over 11 | Blotter | 30.0 | 42.5 | 11.0 | 1.0 | 152.0 | 35.5 | 84.5 | --- |
| GW49 | Whole | Over 7 | Blotter | 32.5 | 38.5 | 8.0 | 0.0 | 133.5 | 41.1 | 79.0 | --- |
| GW49 | Whole | 7/8 | Field | 18.4 | 5.0 | 0.3 | 0.0 | 29.2 | 77.6 | 23.7 | 40.3 |
| GW49 | Whole | 7/9 | Field | 22.3 | 6.7 | 0.7 | 0.8 | 38.6 | 74.8 | 29.8 | 41.5 |
| GW49 | Whole | 8/9 | Field | 22.6 | 8.4 | 0.5 | 0.0 | 40.9 | 71.7 | 31.5 | 44.9 |
| GW49 | Whole | 7/10 | Field | 20.8 | 12.8 | 0.6 | 0.8 | 45.4 | 63.4 | 32.8 | 44.5 |
| GW49 | Whole | 9/10 | Field | 25.3 | 12.0 | 0.3 | 0.0 | 49.5 | 68.8 | 36.8 | 43.2 |
| GW49 | Whole | 9/11 | Field | 23.0 | 13.1 | 1.1 | 0.0 | 52.4 | 61.8 | 37.2 | 40.9 |
| GW49 | Whole | 10/11 | Field | 23.0 | 14.2 | 1.5 | 1.6 | 56.0 | 59.3 | 38.8 | 40.7 |
| GW49 | Whole | Over 11 | Field | 22.9 | 20.7 | 5.4 | 0.5 | 82.8 | 46.3 | 49.5 | 54.5 |
| GW49 | Whole | Over 7 | Field | 22.3 | 13.2 | 2.1 | 0.1 | 55.2 | 59.3 | 37.6 | 41.3 |
| GW267 | Whole | Over 7 | Blotter | 39.0 | 31.0 | 4.5 | 0.0 | 114.5 | 52.3 | 74.5 | --- |
| GW267 | Burred | 8/11 | Blotter | 30.0 | 42.5 | 7.0 | 1.0 | 140.0 | 37.3 | 80.5 | --- |
| GW267 | Decort. | 6/7 | Blotter | 71.5 | 17.5 | 0.0 | 0.0 | 106.5 | 80.3 | 89.0 | --- |
| GW267 | Decort. | 7/10 | Blotter | 47.0 | 29.0 | 1.0 | 0.0 | 108.0 | 61.0 | 77.0 | --- |
| GW267 | Decort. | Over 10 | Blotter | 27.5 | 22.5 | 3.5 | 0.0 | 86.0 | 51.4 | 53.5 | --- |
| GW267 | Whole | Over 7 | Field | 17.0 | 9.2 | 2.9 | 0.1 | 44.3 | 58.2 | 29.2 | 38.7 |
| GW267 | Burred | 8/11 | Field | 21.5 | 9.1 | 1.4 | 0.1 | 44.3 | 67.0 | 32.1 | 31.6 |
| GW267 | Decort. | 6/7 | Field | 21.4 | 4.3 | 0.1 | 0.0 | 30.2 | 82.9 | 25.8 | 28.4 |
| GW267 | Decort. | 7/10 | Field | 17.3 | 7.3 | 1.1 | 0.1 | 35.3 | 67.3 | 25.7 | 32.7 |
| GW267 | Decort. | Over 10 | Field | 7.8 | 3.0 | 0.3 | 0.0 | 14.6 | 70.3 | 11.1 | 17.0 |
| GW59-43A1 | Whole | Over 7 | Blotter | 39.0 | 23.5 | 5.5 | 1.0 | 106.5 | 56.5 | 69.0 | --- |
| GW49-42A | Whole | Over 7 | Blotter | 27.5 | 27.0 | 7.0 | 1.0 | 106.5 | 44.0 | 62.5 | --- |
| GW49-41A | Whole | Over 7 | Blotter | 35.0 | 19.5 | 7.5 | 1.0 | 101.0 | 55.1 | 63.5 | --- |
| GW59-45R | Whole | Over 7 | Blotter | 41.0 | 32.0 | 5.0 | 0.0 | 120.0 | 52.6 | 78.0 | --- |
| GW59-44NM | Whole | Over 7 | Blotter | 28.5 | 31.5 | 15.2 | 4.0 | 146.5 | 35.8 | 79.5 | --- |

**TABLE 1—Continued**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GW59-43A1 | Whole | Over 7 | Field | 16.3 | 10.8 | 3.0 | 0.3 | 48.1 | 53.8 | 30.3 | 45.2 |
| GW49-42A | Whole | Over 7 | Field | 18.3 | 11.3 | 2.4 | 0.3 | 49.4 | 56.7 | 32.3 | 46.4 |
| GW49-41A | Whole | Over 7 | Field | 20.3 | 9.1 | 1.8 | 0.2 | 44.6 | 64.6 | 31.4 | 44.2 |
| GW59-45R | Whole | Over 7 | Field | 26.1 | 17.8 | 2.7 | 0.1 | 68.6 | 56.9 | 45.9 | 57.2 |
| GW59-44NM | Whole | Over 7 | Field | 18.1 | 12.9 | 4.3 | 0.8 | 59.7 | 50.3 | 36.0 | 40.8 |
| B333 | Whole | Over 7 | Blotter | 35.5 | 26.0 | 1.0 | 0.0 | 90.5 | 57.3 | 62.0 | --- |
| B333 | Whole | Thru 7 | Blotter | 35.5 | 6.5 | 0.5 | 0.0 | 50.0 | 83.5 | 42.5 | --- |
| B333 | Whole | Thru 6 Slotted over 6 Round | Blotter | 8.0 | 0.0 | 0.0 | 0.0 | 8.0 | 100.0 | 8.0 | --- |
| B333 | Whole | Over 7 | Field | 26.8 | 12.2 | 0.7 | 0.0 | 53.2 | 67.3 | 39.8 | 58.8 |
| B333 | Whole | Thru 7 | Field | 23.3 | 3.3 | 0.0 | 0.0 | 30.0 | 87.3 | 26.7 | 60.0 |
| B333 | Whole | Thru 6 Sl. Over 6 Rd. | Field | 9.1 | 0.4 | 0.1 | 0.0 | 10.2 | 94.8 | 9.6 | 127.5 |
| GW34+GW201 | Dow[c] Pellets | 7/9 | Blotter | 40.0 | 6.5 | 0.0 | 0.0 | 53.0 | 86.0 | 46.5 | --- |
| GW34+GW201 | Pellets[d] | 7/9 | Blotter | 47.0 | 14.0 | 0.0 | 0.0 | 75.0 | 77.0 | 61.0 | --- |
| GW34+GW201 | Pellets[e] | 7/9 | Blotter | 39.5 | 25.5 | 1.5 | 0.0 | 95.0 | 59.4 | 66.5 | --- |
| GW34+GW201 | Check Seg. | 7/9 | Blotter | 53.0 | 24.5 | 0.0 | 0.0 | 102.0 | 68.4 | 77.5 | --- |
| GW34+GW201 | Dow[c] Pellets | 7/9 | Field | 22.3 | 2.2 | 0.0 | 0.0 | 26.6 | 91.4 | 24.4 | 50.2 |
| GW34+GW201 | Pellets[d] | 7/9 | Field | 21.9 | 5.5 | 1.6 | 0.0 | 33.4 | 78.8 | 27.8 | 44.5 |
| GW34+GW201 | Pellets[e] | 7/9 | Field | 24.1 | 8.7 | 0.1 | 0.0 | 41.7 | 88.1 | 32.8 | 43.9 |
| GW34+GW201 | Check Seg. | 7/9 | Field | 21.1 | 4.7 | 0.5 | 0.0 | 31.9 | 80.2 | 26.3 | 31.3 |
| GW92 | Filtrol[f] Pellets | 7/9 | Blotter | 58.5 | 20.5 | 0.5 | 0.5 | 103.0 | 73.1 | 80.0 | --- |
| GW92 | Check Seg. | 7/9 | Blotter | 58.5 | 22.0 | 0.0 | 0.0 | 102.5 | 72.2 | 81.0 | --- |
| GW92 | Filtrol[f] Pellets | 7/9 | Field | 20.6 | 7.0 | 0.8 | 0.0 | 36.8 | 72.8 | 28.3 | 35.7 |
| GW92 | Check Seg. | 7/9 | Field | 17.9 | 6.0 | 0.7 | 0.0 | 31.9 | 72.8 | 24.6 | 31.1 |

[a]Sizes are all in 64ths inch, e.g., 7/9 indicates range of 7/64 inch to 9/64 inch.

[b]Based on total seedlings.

[c]Pellet No. 803-2-GW, treated with 10 percent Arasan + 10 percent superphosphate + graphite.

[d]Pellet No. 801½-1-GW, treated with 7½ percent yellow Cuprocide + 10 percent superphosphate.

[e]Pellet No. 803-1-GW, treated with 10 percent Arasan + 10 percent superphosphate.

[f]Coated with 38 percent $P_2O_5$ equal to 5 percent of uncoated seed.

**Table 2.**—Summarized Results. Germination Study, Longmont, 1947. Blotter germination, averages for 2 samples of 100-seed units each. Field germinations, average for 13 replicates, all converted to 100-seed units each.

| Variety | Treatment | Size[a] | Where germ. | Number of Seedlings per 100-Seed Units | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 or more | Total seedlings | % singles | % germ. | % potential |
| GW85-46R | Seg. | 7/9 | Blotter | 48.5 | 30.0 | 3.0 | 0.0 | 117.5 | 59.6 | 81.5 | --- |
| GW85-46R | Decort. | 7/9 | Blotter | 50.5 | 28.0 | 2.5 | .5 | 116.0 | 62.0 | 81.5 | --- |
| GW85-46R | Whole | 7/9 | Blotter | 40.0 | 39.5 | 4.0 | .5 | 133.0 | 47.7 | 84.0 | --- |
| GW85-46R | Seg. | 7/9 | Field | 35.4 | 17.0 | .5 | 0.0 | 71.1 | 66.9 | 53.0 | 60.5 |
| GW85-46R | Decort. | 7/9 | Field | 31.5 | 11.5 | .2 | 0.0 | 55.2 | 73.6 | 43.2 | 47.6 |
| GW85-46R | Whole | 7/9 | Field | 33.5 | 20.4 | .8 | 0.0 | 76.8 | 60.9 | 54.7 | 63.1 |
| GW85-46R | Seg. | 7/10 | Blotter | 44.0 | 32.5 | 3.5 | .5 | 121.5 | 55.2 | 80.0 | --- |
| GW85-46R | Decort. | 7/10 | Blotter | 37.0 | 32.0 | 6.5 | .5 | 122.5 | 48.1 | 76.0 | --- |
| GW85-46R | Whole | 7/10 | Blotter | 42.5 | 27.5 | 3.0 | 0.0 | 106.5 | 58.3 | 73.0 | --- |
| GW85-46R | Seg. | 7/10 | Field | 34.6 | 18.0 | .7 | 0.0 | 72.6 | 65.7 | 53.0 | 59.8 |
| GW85-46R | Decort. | 7/10 | Field | 31.1 | 15.4 | .9 | 0.0 | 64.5 | 66.4 | 47.4 | 52.7 |
| GW85-46R | Whole | 7/10 | Field | 35.8 | 15.2 | .2 | 0.0 | 66.8 | 70.1 | 51.1 | 62.7 |
| GW85-46R | Whole | 9/11 | Blotter | 22.5 | 53.5 | 12.5 | .5 | 169.0 | 25.3 | 89.0 | --- |
| GW85-46R | Whole | Over 11 | Blotter | 9.5 | 40.0 | 26.0 | 3.5 | 181.5 | 11.4 | 84.0 | --- |
| GW85-46R | Whole | Over 7 | Blotter | 26.0 | 41.5 | 15.5 | .5 | 157.5 | 31.0 | 83.5 | --- |
| GW85-46R | Whole | 9/11 | Field | 26.2 | 35.1 | 4.0 | .3 | 108.2 | 40.1 | 65.6 | 64.0 |
| GW85-46R | Whole | Over 11 | Field | 19.6 | 30.6 | 13.5 | 1.7 | 127.8 | 30.4 | 65.2 | 70.4 |
| GW85-46R | Whole | Over 7 | Field | 26.2 | 27.4 | 4.8 | 0.0 | 95.3 | 45.1 | 58.4 | 60.5 |
| GW64-46A | Whole | Over 7 | Blotter | 17.0 | 42.5 | 25.0 | 5.5 | 199.0 | 19.0 | 90.0 | --- |
| GW201-46A | Whole | Over 7 | Blotter | 19.0 | 43.0 | 24.5 | 0.0 | 178.5 | 22.3 | 86.5 | --- |
| GW64-46A | Seg. | 7/10 | Blotter | 50.5 | 23.5 | 6.0 | 0.0 | 115.5 | 62.8 | 80.0 | --- |
| GW201-46A | Seg. | 7/10 | Blotter | 50.5 | 22.5 | 3.5 | 0.0 | 106.0 | 65.9 | 76.5 | --- |
| GW64-46A | Whole | Over 7 | Field | 20.8 | 20.1 | 8.3 | 1.3 | 91.1 | 41.4 | 50.4 | 45.8 |
| GW201-46A | Whole | Over 7 | Field | 19.9 | 24.2 | 9.0 | 2.4 | 105.2 | 36.3 | 55.6 | 58.9 |
| GW64-46A | Seg. | 7/10 | Field | 26.6 | 12.5 | .4 | 0.0 | 52.7 | 68.3 | 39.4 | 45.6 |
| GW201-46A | Seg. | 7/10 | Field | 33.8 | 15.7 | .5 | 0.0 | 66.7 | 68.7 | 50.0 | 62.9 |
| B333 | Whole | 7/9 | Blotter | 52.5 | 13.0 | 0.0 | 0.0 | 78.5 | 81.2 | 64.5 | --- |
| B401 | Whole | 7/9 | Blotter | 40.5 | 10.5 | 0.0 | 0.0 | 61.5 | 79.6 | 51.0 | --- |
| B333 | Whole | 7/9 | Field | 32.5 | 5.5 | 0.0 | 0.0 | 43.5 | 85.7 | 38.0 | 55.4 |
| B401 | Whole | 7/9 | Field | 32.2 | 7.6 | 0.0 | 0.0 | 47.4 | 80.8 | 39.8 | 77.1 |

**TABLE 2—Continued**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B333 | Whole | 7/10 | Blotter | 45.5 | 26.5 | 1.0 | 0.0 | 101.5 | 62.3 | 73.0 | --- |
| B401 | Whole | 7/10 | Blotter | 49.5 | 26.5 | .5 | 0.0 | 104.0 | 64.8 | 76.5 | --- |
| B333 | Whole | 7/10 | Field | 35.9 | 11.3 | .1 | 0.0 | 58.7 | 82.8 | 47.3 | 57.9 |
| B401 | Whole | 7/10 | Field | 34.3 | 12.3 | .1 | 0.0 | 59.3 | 80.8 | 43.3 | 57.1 |
| B333 | Whole | 9/11 | Blotter | 45.5 | 44.0 | 0.0 | 0.0 | 133.5 | 50.8 | 89.5 | --- |
| B401 | Whole | 9/11 | Blotter | 46.5 | 30.0 | .5 | 0.0 | 108.0 | 60.3 | 77.0 | --- |
| B333 | Whole | 9/11 | Field | 34.1 | 17.8 | .1 | 0.0 | 70.1 | 66.5 | 52.0 | 52.5 |
| B401 | Whole | 9/11 | Field | 35.6 | 13.7 | 0.0 | 0.0 | 62.9 | 73.3 | 49.3 | 58.3 |
| B333 | Whole | Over 11 | Blotter | 26.5 | 66.5 | 5.0 | 0.0 | 174.5 | 27.1 | 98.0 | --- |
| B401 | Whole | Over 11 | Blotter | 31.0 | 60.0 | .5 | 0.0 | 152.5 | 33.8 | 91.5 | --- |
| B333 | Whole | Over 11 | Field | 27.5 | 29.8 | 1.4 | 0.0 | 91.5 | 47.8 | 58.8 | 52.4 |
| B401 | Whole | Over 11 | Field | 30.6 | 26.8 | 1.1 | 0.0 | 87.6 | 52.5 | 58.5 | 57.4 |
| B333 | Whole | Over 6 | Blotter | 43.0 | 35.5 | 1.5 | 0.0 | 118.5 | 54.0 | 80.0 | --- |
| B401 | Whole | Over 6 | Blotter | 37.0 | 43.0 | 0.0 | 0.0 | 123.0 | 46.3 | 80.0 | --- |
| B333 | Whole | Over 6 | Field | 31.6 | 17.0 | .4 | 0.0 | 66.8 | 64.3 | 49.0 | 56.4 |
| B401 | Whole | Over 6 | Field | 29.3 | 17.6 | .3 | 0.0 | 65.2 | 63.4 | 47.1 | 53.0 |
| B402 | Whole | Thru 6 | Blotter | 43.0 | .5 | 0.0 | 0.0 | 44.0 | 99.0 | 43.5 | --- |
| B402 | Whole | Slotted Over 6 Round | Field | 25.9 | .5 | .1 | 0.0 | 27.2 | 97.9 | 26.5 | 61.7 |
| B401 | Decort. | 6/11 | Blotter | 41.0 | 36.0 | .5 | 0.0 | 114.5 | 52.9 | 77.5 | --- |
| B401 | Decort. | 6/8 | Blotter | 31.0 | 4.0 | 0.0 | 0.0 | 39.0 | 88.6 | 35.0 | --- |
| B401 | Decort. | 8/11 | Blotter | 40.0 | 43.0 | 0.0 | 0.0 | 126.0 | 48.2 | 83.0 | --- |
| B401 | Decort. | Over 11 | Blotter | 37.0 | 47.0 | 3.0 | 0.0 | 140.0 | 42.6 | 87.0 | --- |
| B401 | Decort. | 6/11 | Field | 31.7 | 17.6 | .4 | 0.0 | 68.2 | 64.6 | 49.7 | 59.6 |
| B401 | Decort. | 6/8 | Field | 24.1 | 2.7 | .1 | 0.0 | 29.7 | 89.5 | 26.9 | 76.1 |
| B401 | Decort. | 8/11 | Field | 33.8 | 20.6 | .4 | 0.0 | 76.2 | 61.8 | 54.8 | 60.5 |
| B401 | Decort. | Over 11 | Field | 33.6 | 19.6 | .7 | .1 | 75.0 | 62.3 | 54.5 | 53.6 |

[a]Sizes are all in 64ths inch, e.g., 7/9 indicates range of 7/64 inch to 9/64 inch.
[b]Based on total seedlings.

segmented and whole seed in both years' tests, although no other direct comparisons can be made.

Decorticating the seed appears to have caused some injury to the germs, especially for the larger grades as evidenced by a 17 percent of potential for seed graded over a 10/64-inch screen in 1946 (table 1). The 1947 test was designed so that comparisons could be made directly upon seed of the same variety for the 7/64- to 9/64-inch and 7/64- to 10/64-inch grades, of segmented, decorticated, and whole seed where the respective percentages of potential were found to be 60.2, 50.2, and 62.9 as an average for the two grades of seed; thus there appears to be a loss of 10 percent of potential for the decorticated seed which had been processed for commercial use. However, the double-germ variety B401, which was decorticated only very lightly, produced 62.5 percent of potential as compared with 60.6 percent for the whole seed as an average of all grades for each category. The results of the special tests for segmented, decorticated and whole seed are presented in table 3.

**Table 3.** Summarized Results. Special Test for Segmented, Decorticated and Whole Seed, Longmont, 1947. Averages for three dates of planting for GW85-46R and two planting dates for GW59 and GW268.

| Variety | Kind of seed | Seed size | No. of potential sprouts | No. seedlings emerged | % of potential |
|---|---|---|---|---|---|
| GW85-46R | Whole | Over 7 | 287.15 | 150.8 | 52.5 |
| GW59 | Whole | Over 7 | 202.20 | 79.3 | 38.1 |
| GW268 | Whole | Over 7 | 302.53 | 52.4 | 17.3 |
| Mean | | | ------ | ---- | 36.0 |
| GW85-46R | Seg. | 7/10 | 215.45 | 83.4 | 38.7 |
| GW59 | Seg. | 7/10 | 234.82 | 31.0 | 13.2 |
| GW268 | Seg. | 7/10 | 202.43 | 28.9 | 14.3 |
| Mean | | | ------ | ---- | 22.1 |
| GW85-46R | Decort. | 7/10 | 215.65 | 72.8 | 33.8 |
| GW59 | Decort. | 7/10 | 239.34 | 30.2 | 12.6 |
| GW268 | Decort. | 7/10 | 223.66 | 24.0 | 10.7 |
| Mean | | | ------ | ---- | 19.0 |

The whole seed as used was all from commercial ungraded lots, including the larger seed sizes, which may account for the higher percentage of potential obtained for whole seed in this test. The difference between segmented and decorticated seed is not so large as that obtained in the regular germination study, although the segmented seed appears to be slightly better. The first planting of GW85-46R was made under favorable conditions with an average of 73.1 percent of potential being obtained while the average results for the two later dates gave only 25.9 percent of potential for this variety, which is indicative of the adverse conditions encountered for these plantings.

The pelleted seed tested in 1946 appears to be slightly better than the unpelleted checks with which it was compared for the conditions existing under this test.

## Summary and Conclusions

1. Field germinations produced a considerably higher percentage of singles, for all types of seed, than was obtained in the laboratory. This increase amounted to about 12 percent for this study.

2. Segmented and whole seed of the same grades appear to give about the same results under comparable field conditions.

3. The seed now produced commercially by decorticating resulted in a 10-percent lower potential than segmented or whole seed of the same grades. A special lot of double-germ seed which was polished only lightly in the decorticating process gave as good results as whole seed from this same lot, indicating that there may have been some injury to the commercial seed in connection with the decorticating process.

4. Results from single- or double-germ varieties indicate that the development of such varieties for use on a commercial basis will simplify the problem of supplying the farmer with a high-grade product adaptable to precision planting.

# Report of Seed Germination Committee

Bion Tolman[1]

I.—Washing or Soaking of Seed.

Washing seed can be a more standard procedure than soaking and is generally more convenient. The Committee therefore recommends that washing the seed in running water for a period of 2 hours be made a standard procedure.

II.—Temperature Control.

Present indications are that temperature control within the limits of 20 to 30 degrees centigrade is not a critical factor. The general opinion seems to be that a constant temperature is just as good and more convenient than an alternating temperature. General preference favors a constant temperature between the limits of 25 degrees to 30 degrees centigrade. Germination proceeds more rapidly within this range.

The Committee recommends that some work be done to make the following comparisons: 20, 25, 30 and 35-degree centigrade constant temperatures and 20-30 and 25-30-degree centigrade alternating temperatures. In connection with the alternation of temperature, a quick change in temperature should be compared with letting the change take place gradually.

III.—Mold Problem.

Is it permissible to use such treatments as:

A. Lignisan (ethyl mercury phosphate) 5 p.p.m. or 1:12500 as a seed and blotter dip?

B. Wettable Phygon or Arasan—dilution 1:1000—seed to be soaked for 5 minutes prior to washing in running water?

Would it be more acceptable to show both the treated and untreated germination percentage?

IV.—Description of Abnormals.

The following should definitely be classed as abnormals:

A. Where the cotyledons appear first.

B. Where the cotyledons and root appear at the same time.

C. Where the cotyledons and the tip of the radicle remain in the seed particle and the sprout shows as a loop extending out of the seed particle.

D. If the root or stem is broken to the extent that it cannot produce a normal plant.

[1]Agricultural Research Director, Utah-Idaho Sugar Company, Salt Lake City, Utah.

There is considerable question as to just what should be classed as a mutilated seedling. Some further work is needed along this line. Some seedlings with one cotyledon broken or just the tip of the radicle broken apparently develop into healthy, vigorous plants.

The Committee seriously questions whether browned radicles should be classed as abnormals. Browning of the radicle can be overcome by washing the seed and by altering the substratum on which the seed is germinated, consequently it would appear that they should not be classed as abnormals.

Someone should work up a series of photographs showing just what should be classed as abnormal.

V.—DETERMINATION OF PURITY.

Determination of purity is much more difficult in processed seed than in whole seed. This is obviously due to the fact that the seed has been broken into fragments. The question as to what should be classed as a seed unit and what should be classed as inert material is sometimes difficult to determine. Some definite sieve size should be indicated for use in purity determination. Should all seed fractions larger than 5/64-inch in diameter be classed as a seed unit and all smaller than this size be classed as inert material? We should know whether this screen size should be set at 4/64, 5/64 or 6/64. The above sizes refer to the diameter of round holes in the screen to be used in making the separation. Some work should be done on this point.

VI.—TESTING METHODS.

It was the consensus of the Committee that in most tests they would much prefer to stay with blotters, and check only when necessary on Kimpac or sand. The necessity of checking further than the blotter test would be governed by two factors:

A. Excess browning of the radicles.

B. Discrepancy between the crack test and the blotter test.

VII.—CRACK TEST.

It is recommended that a crack test be run on all low samples. This test can be rapidly run by cracking the seed with a hammer on a heavy steel plate and the possible potential germination can be quickly determined. When the blotter germination runs considerably lower than the potential as indicated by the crack test, then special procedures should be followed.

VIII.—GENERAL RECOMMENDATIONS—*not covered above.*

A. Drying of Seed. After washing, the seeds may be either air dried or thoroughly blotted to remove all excess moisture before they are placed on the blotters.

B. Moistening of the Blotters. Submerge the blotters in water and then drain them until all free water is eliminated.

C. Maintain plenty of water on the blotters throughout the germination period, but in no case permit the formation of a water film.

D. Space the seeds on the blotter far enough apart to avoid all contact between either seeds or sprouts. Blotter indentations are helpful in this regard.

IX.—VITAL DATA NEEDED.

A. Whole Seed.

1. Germination percentage.
2. Purity.
3. Number of seedballs per pound.

B. Segmented Seed.

1. Germination percentage.
2. Purity.
3. Percentage of singles.
4. Number of germinating seed units per pound.

Only normal sprouts should be counted in reporting germition of the seed.

# Beet Seed Germination Methods

C. W. Doxtator and A. R. Downie[1]

The procedures used by the American Crystal Sugar Company in germination tests of sugar beet seed follow the general recommendations of the Committee on Standardization of Experimental Methods (1).[2] The procedure now used for whole and processed seed will be briefly outlined.

A 1-pound sample of seed is reduced in a Boerner Grain Sampler to a little more than 200 seeds. From this amount 2 samples of 100 seeds are counted out, placed to soak in a seed washer (2) which is connected to the tap-water outlet by means of a rubber tube. Seed samples are washed from 5 to 6 hours. The volume of water used during the washing period is approximately 8 gallons. No attempt is made to control the temperature of the wash water. After washing, the seed baskets are taken out of the washer and allowed to drain for 5 minutes. Standard germination blotters, cut 9 x 16 inches, are soaked in tap water and after the excess moisture has drained off the 100-seed sample is spread evenly over half of the blotter—the other half being used as a cover. A Minnesota Seed Germinator is used. No temperature control has been used on the germination cabinet the past 2 years, consequently, germination tests are conducted during the spring and fall when temperatures normally fall within the range of 21 to 26 degrees centigrade. First germination counts are made on the third day, and the final count on the tenth day.

### Comparison of Germination Tests

The Western Seed Production Corporation, during 1946 and 1947, furnished the Rocky Ford Beet Seed Office germination samples of seed increases of American Crystal Sugar Company varieties, taken from their cleaning plants at Cashion, Arizona, and Mesquite, New Mexico. Each of these samples was germinated at the Rocky Ford Laboratory and the results compared with the germination percentages furnished the Western Seed Production Corporation by a Commercial Seed Laboratory. Comparison of these tests for these 2 years is given in table 1.

It will be observed that the Western Seed Production Corporation germinations were slightly higher than those obtained at Rocky Ford in 1946, and slightly lower in 1947. The higher germinations obtained at Rocky Ford in 1947 may be partly due to the fact that germination tests were made in September, at which time no excessively high temperatures were obtained in the germinator. In general, there is good agreement between the two laboratories for the 136 samples tested in the 2-year period 1946-47.

[1]Plant Breeder and Plant Pathologist, American Crystal Sugar Company, Rocky Ford, Colorado.
[2]The numbers in parentheses refer to literature cited.

## Present Germination Problems

As indicated above, temperature control is one of the problems encountered during the mid-summer season at Rocky Ford. Germination tests consequently are avoided during the hot summer months. In both the spring and the fall, temperatures in the germinator range from 21 degrees to 26 degrees centigrade, at which level germination is quite vigorous and consistent. Mold growth has not been a problem in germination work since the 6-hour soak in running water was begun, except in very rare instances. If a seed sample is obtained which has a very heavy spore load, fungus control is obtained by soaking the seed in wettable Phygon or Arasan in a dilution of 1-to-1,000 for 5 minutes prior to washing in running water.

One of the recent problems in processed-seed germinations at this time is the determination of purity. Processed seed usually contains large numbers of seed fragments which are desired if viable, but which, if they are inert, should be screened out and considered in the purity determination. The question of what should be classed as inert material in processed beet seed is often a problem, and one which should be given further consideration.

**Table 1.** Comparison of germination tests on American Crystal Sugar Company commercial seed increases, 1946 and 1947.

| Varieties | Number of samples tested | | American Crystal Sugar Company | Western Seed Production Corporation |
|---|---|---|---|---|
| | | 1946 | | |
| American No. 1 a | 31 | | 90.22 | 92.64 |
| American No. 1 b | 14 | | 87.17 | 88.73 |
| American No. 3 | 23 | | 89.50 | 90.21 |
| | | Average | 89.349 | 91.013 |
| | | 1947 | | |
| American No. 2 | 5 | | 84.90 | 83.00 |
| American No. 3 a | 19 | | 85.58 | 85.50 |
| American No. 3 b | 33 | | 84.62 | 83.91 |
| U. S. No. 22 | 11 | | 92.50 | 91.35 |
| | | Average | 86.184 | 85.491 |
| Average 1946-47 | | | 87.766 | 88.252 |

Correlation coefficient on 1947 tests: r= +0.88

## Literature Cited

(1) 1942. Report of the Committee on Standardization of Experimental Methods. Proc. Amer. Soc. Sug. Beet Tech. p. 595-599.

(2) GADDIE, R. S.
1946. Beet seed germination technique used by the Utah-Idaho Sugar Company. Proc. Amer. Soc. Sug. Beet Tech. p. 287-288.

# Outline of Material for Discussion

at

# Seed Germination Symposium

C. E. Cormany[1]

Germination Problems:

1.—Erratic readings on duplicate samples caused by:
   a.—Poor blending of original sample. Use Boerner Sampler.
   b.—Drying out of certain parts of germinator—corrected by adding adequate water supply within oven itself.
   c.—Chemical fumes for a long time an unknown cause of poor germination. When finally located, corrected by moving location of germinator to another room.
2.—Handling large number of samples with limited help.
   a.—Take detail count only when necessary. Formerly took detail on whole-seed samples and all processed seed. At present, details only on composite samples of various lots.
   b.—Day distribution to avoid reading on Sundays. Place samples in germinator on Monday, Tuesday, Wednesday, Friday and Saturday. Counts of 3-7-10 days and 2 weeks do not fall on Sunday.
3.—Adjusting germinator procedure so results will compare closely with check run in greenhouse-soil planting. This was matter of personal adjustment of operator as regards closeness of calling malformed sprouts, etc. Also found a continuous 25° centigrade temperature helped in this respect.

Germination Procedure:

1.—Assign sample laboratory number for proper identification.
2.—Secure sample of approximately 500-seed units by use of Boerner sampler.
3.—Place these 500-seed units in test tube, and soak in running water for 2 hours.
4.—Drain to remove free moisture.
5.—Soak for 5 minutes in solution of 2 grains potassium permanganate per 4 ounces of water. Retards mold growth.
6.—Drain for about 2 minutes.
7.—Mark dry paper towel with sample number and then moisten.
8.—Place pattern for 100 seeds on paper towels and fill with seeds.
9.—Remove pattern, place top layer of towel on seed and place in germinator.
10.—Place duplicate, triplicate, etc., in different locations in germinator.

[1]Chief Agronomist, Holly Sugar Corp., Sheridan, Wyoming.

MISCELLANEOUS NOTES:

Temperature of germinator now 25° C. continuous. Originally was 20° at night and 30° in daytime.

Pattern for seed on towel made of 1/8-inch rubber gasket material—seed holes 5/16 inch in diameter, and holes arranged 8x12 plus 4 holes on top.

Paper towels numbered while dry, wet before seed placed on them.

Counts made 3rd, 7th and 10th days.

Sprouts pulled out with tweezers to make sure every sprouted germ is removed from its locule.

Injured or malformed sprouts not counted. They are left in upper or non-germinating area of towel until next time (through 10 days) to see if they qualify as normals.

ON 3RD DAY:

In segregating germinating seed the 3rd day, the seed is placed as follows:

a.—Top section: Non-germinating (these always move toward top)

b.—Next section: Singles

c.—Next section: Doubles

d.—Bottom section: Multiples.

ON 7TH DAY:

a.—Multiples remain in their section at bottom.

b.—If any more sprouted in the "doubles" section they are moved down to "multiple" section.

c.—If any more sprouted in "singles" section they are moved down to "doubles" section.

d.—Any germinating in the "non-germinating" section are moved to their respective section, such as singles, doubles or multiples.

ON 10TH DAY:

The procedure is same as on 7th day.

PAPER DOLL:

Made of paper towels. Counts never are detailed. Every sprouted seed unit is thrown out at each reading.

# Method of Germinating Segmented Sugar Beet Seed Used by the Great Western Sugar Company

H. B. Saxton[1]

The method used by The Great Western Sugar Company in laboratory germination tests of segmented sugar beet seed is not unlike procedures used by other seed-germinating laboratories (1,2,3).[2]

The original sample of segmented sugar beet seed received from the segmenting station is reduced by the use of the Boerner Sampler. Small particles are rejected by screening the reduced sample over a 10-mesh sieve, having openings of about .075 inch. No further rejection of seed particles is made. Four Boerner divided portions of about 100-seed particles are made from the screened portion of the reduced sample. One hundred seed particles are counted, without selection, from each portion.

The counted seeds are soaked for 2 hours in running tap-water in a Utah-Idaho seed washer (2). The baskets are removed from the seed washer and the seed is dried somewhat by placing the baskets on a folded towel. Germination is done in depressions in folded wet blotters (6 inches by 9½ inches) in various makes of seed germinators at 27 degrees to 30 degrees centigrade for a period of 10 days. Care is taken to add just enough water to the blotters to maintain a dark color; excess free water is avoided.

The sprouts are counted each day after the second for 8 consecutive days. At each count the normal sprouts are removed from the seed particles. Seed units producing single sprouts are placed on a second blotter for identification and left for future examination to see if they will become seed particles producing double sprouts. Doubles are rejected at the time they are counted and a record of them is kept.

In reporting the germination of a sample, the following information is included: Number of seedballs per pound, number of germinating seedballs per pound, and percentage of the germinating seedballs which show normal single sprouts as an average of 4 samples of 100-seed particles each. For computing the number of seedballs per pound, 1/40 of a pound of the screened seed is weighed and counted as a basis for determining the seedballs per pound. For segmented seed the following types of sprouts are considered abnormal and are not counted:

1.—Cotyledons appear first.

2.—Cotyledons and root appear at the same time.

[1]Chief Chemist, The Great Western Sugar Company, Longmont, Colorado.

[2]The numbers in parentheses refer to literature cited.

3.—Tip of root and cotyledons remain fixed in the seed particle and the hypocotyl shows as a loop out of the seed particle. Such are left on the blotter and are considered normal if the root tip emerges.

4.—Root tip broken off.

Trouble with mold may sometimes be controlled by a thorough cleaning of the germinator and sun-drying the trays. When this fails the washed seed may be soaked for 5 minutes in a solution of Lignasan containing 1 part Lignasan to 10,000 parts water before placing in the germinator.

## Literature Cited

(1) ATWATER, BETTY RANSOM
1946. The importance of standardized germination methods in marketing of sugar beet seed. Proc. Amer. Soc. Sugar Beet Tech., pp. 281-283.

(2) GADDIE, ROBERT S.
1946. Beet seed germination technique used by the Utah-Idaho Sugar Company. Proc. Amer. Soc. Sugar Beet Tech., pp. 287-288.

(3) HILL, K. W.
1946. Standard methods of laboratory germination of sugar beet seed in Canada. Proc. Amer. Soc. Sugar Beet Tech., pp. 283-284.

# Method of Germinating Segmented Beet Seed

H. B. Saxton[1]

The large sample of beet seed received from the segmenting plant should be reduced by passing it through the Boerner sample divider.

*Selecting the Sample.*—When the original sample has been reduced to about 1/20 pound by passing it through the Boerner sampler it is to be placed on a 10-mesh sieve which has openings of about .075 inch and the small particles screened out. The screened sample is then to be returned to the Boerner sample divider for further reduction. One portion of the screened sample is saved from which 1/40 pound is to be weighed and counted. Multiply this number by 40 and record this as seedballs per pound.

The other portion of the screened sample is to be further reduced through the Boerner sampler. When the reduced sample has slightly over 400-seed particles it is passed through the sampler again and both portions saved. Each half is reduced once more making 4 portions of about 100-seed particles each. From each of these 4 portions 100-seed particles are to be counted without selection. This will make 4 germination tests of 100-seed particles for each sample of beet seed. Report the average germination of the 4 portions. The germination may be reduced to 2 portions of 100-seed particles for each sample when the number of samples become so great that the capacity of the germinator is not sufficient to hold all of them, or in case there is not sufficient time to process all of the samples if 4 germinations are made on each sample. However, when only 2 portions of 100-seed particles are germinated and they differ 10 percent or more in germination the sample is to be reset for a second germination.

*Preparing the Sample for Germination.*—When the sample has been reduced to 4 portions of approximately 100-seed particles, spread each portion out on some flat surface and count out without selection 100-seed particles from each. After the 4 lots of 100-seed particles have been secured place each in a separate small-screen basket of the Utah-Idaho seed washer and run tap-water through the seed washer for two hours. This will wash the seed in running water for 2 hours. At the end of the 2-hour washing period, remove the screen baskets from the seed washer and place them on a towel for a few minutes to remove the water film from the seed, then plant with no further treatment in folded wet blotters.

*Mold Control.*—When trouble is experienced with mold and cleaning-up and sun-drying the trays does not stop the condition, the following procedure is suggested.

After air-drying the seed somewhat in the small-screen baskets on the towel as stated above, place the baskets containing the seed in a shallow

[1]Chief Chemist, The Great Western Sugar Company, Longmont, Colorado.

pan and soak the seed for 5 minutes in a solution of Lignasan containing 1 part Lignasan in 10,000 parts water. After the 5-minute soaking in the Lignasan solution, remove the basket from the solution and air-dry the seed in the basket a few minutes to remove the water film, then plant with no further treatment in folded wet blotters.

*Preparing Blotters.*—Place on each blotter your laboratory number with other necessary information before the blotter is wet. Use some suitable pencil for marking the blotters. Each 100-seed particle will require two blotters, one for the original 100-seed particle and one for the seed particles producing one sprout. Printed forms will be furnished for keeping other necessary information.

After the blotters are properly labeled soak in tap-water and then make 100 small round depressions in one-half of each blotter at one end of the blotter, by some suitable method. The depressions should be about one-half inch apart each way. Ten rows of ten holes each makes a good method for easy counting. After the depressions are made fold the other half of the blotter over as a cover. The blotters are now ready to receive the seed.

*Placing Seed on the Blotters.*—Place one seed particle in each depression making 100-seed particles per each blotter containing the original seed. The companion blotter which is to receive the seed particles which have developed one sprout is to be placed along side of the blotter containing the original seed particles but no seed will be placed on this blotter until after the first sprout count.

After the seed is placed in the depressions on one end of the blotter the other half is folded over the seed so that it is held firmly between the two halves of the blotter.

The seed is now ready for the germinator.

*Preparing the Germinator.*—The germinator should be so constructed that an even temperature can be maintained at all times inside the germinator. If the room temperature is held close to the required germinating temperature, there will be little difficulty in maintaining the proper temperature in the germinator. If the room temperature drops several degrees below the temperature to be held in the germinator some difficulty may be encountered unless proper insulation and heating facilities are provided. Some of the difficulties will be as follows:

1. Excess sweating of the inner walls of the germinator.
2. Dripping of water condensed on the upper part of the germinator onto the upper tray of blotters.
3. The uneven drying of the blotters in some locations in the germinator.
4. Difficulty of holding the proper temperature in the germinator.

If the temperature of the room, over the week end be allowed to fall below 20° centigrade for fuel economy sake, some provision should be made

to control the temperature of the outside walls of the germinator. A good insulation method might be used. One good system, as used at Longmont, is to build a complete housing, with space between, around the germinator and control the temperature in the space slightly below the temperature in the germinator by using a bank of lights controlled by a thermostat.

It is well to place a wet towel on the top tray for moisture control and not use the top tray for germinating blotters.

In order to force a proper circulation of the hot air and to prevent the trays directly over the heating unit from becoming too warm, the lowest tray should be completely covered with some poor heat-conducting material such as asbestos. A shallow pan filled with water may have to be placed on this covered tray in order to prevent the blotters from drying too rapidly.

*Temperature of the Germinator.*—The temperature of the germinator should be held as near 30° centigrade as possible, but not to go above this point. The minimum temperature will be determined by the range in temperature you are able to maintain. If the room in which the germinator is placed is properly heated or the germinator is insulated and heated on the out side you should be able to hold the temperature about 27° to 30° centigrade without any difficulty. If the temperature of the room reaches a point above 30° centigrade for any length of time, you will not be able to hold the germinator at 30 degrees. If the room temperature falls too low the temperature in the germinator may drop to a point where the light bulbs or other heating device will not be able to hold the germinator at the required temperature.

Arrangements must be made to have the room where the germinator is located heated at all times, especially over the week end and early in the Spring, when normally temperatures are allowed to drop in the factory laboratory.

The temperature of the germinator should be regulated before the seed is placed in it.

*Placing the Seed in the Germinator.*—When the germinator temperature has been regulated, the blotters containing the seed are placed on the trays and the latter placed in the germinator. At the same time the blotters for the single-germ particles may be placed on the same tray so they will be ready when needed after the first count.

*Germinator Space.*—If the number of samples at any one time become so great that the germinator will not hold them, the blotters may be placed two deep on the tray. If this is done the position of the blotters should be changed each time an examination is made, the one on the top being placed underneath and the one underneath being placed on top.

*Securing Germination Data.*—After the seed has been placed in the germinator all future operations will consist of securing the following data and keeping the blotters moistened.

1. Number of germinating seed particles.
2. Number of seed particles producing only one normal sprout.
3. Number of seed particles producing two or more normal sprouts.

From the above information other calculations are made.

*In securing these data proceed as follows:* The first examination should be made the second day after the seed is placed in the germinator, not more than 48 hours after the seed is placed in the germinator. If the first examination is delayed too long some sprouts may have become too far advanced making accurate observations impossible.

*After the first examination all samples must be examined every day. This means a 7-day-a-week job.*

*Moisture in Blotters.*—Water must be added from time to time to hold the moisture content of the blotters at the proper level. The only measure of the moisture content of the blotters we have found practical is their color. The blotters should be moist enough at all times to maintain the same dark color as when the blotters are saturated. Excess free water on the blotters should be avoided.

*First Examination.*—In making the first examination proceed as follows: At this point all of the 100-seed particles will be on one blotter. Each particle that shows a sprout must be examined carefully. First you must determine whether or not the sprout is normal. If the sprout is normal the root will appear first. Normal roots will be tapering and ending in a rounded point. As development of the root advances the root hairs will develop making the root appear somewhat like a round brush with no bristles for a short distance back from the end. These root hairs do not always develop.

The following will be designated as abnormal sprouts:

1. Where the cotyledons (seed leaves) appear first.
2. Where the cotyledons and root appear at the same time.
3. Where the tip of the root and the cotyledons remain fixed in the seed particle and the stem shows as a loop extending out of the seed particle.
4. If the root appears first but has the end broken off. In such cases the root will be minus the tapering, rounded point and will present an extremity which is straight across instead of rounded.

Some sprouts which at first appear to be abnormal may, on further development, become normal. The loop stem sprouts are left for another day after they emerge to see if the root tip will come out and make normal sprouts.

Some authorities on beet-seed germination believe the blunt root-tip sprouts will make healthy plants. The sprouts with the blunt root tip are left in the seed particles for another day and if they develop normally they are counted as normal sprouts.

The next step is to remove these sprouts completely from the seed particles. This can best be done with a needle or fine-pointed tweezers.

If only one normal sprout has appeared the seed particle should be placed on the blotters prepared for single-sprout seed particles. If the sprout is abnormal the seed particle should be returned to the blotter from which it was taken. All seed particles which produce nothing but abnormal sprouts, or no sprouts at all, shall be termed non-germinating. Should two sprouts appear from one seed particle at the same time and one is abnormal this seed particle will be placed on the blotter prepared for singles. If both sprouts are normal the seed particle shall be discarded and a record kept of the same on a form provided for reporting the germination results.

At the end of the first examination you will have some seed particles still remaining on the first blotter, some on the blotter designated singles, and a record of the number of seed particles producing two or more sprouts. The sum of the three should add up to 100.

*Second Examination.*—The second examination should be made the day following the first one. In examining the blotters on which the original sample was placed, proceed as in the first examination. All the seed particles on the blotter designated as "singles" will be examined next. If any normal sprouts have developed on the blotters designated as singles, discard the particle or particles producing them and increase the record of particles producing multiple sprouts. Also reduce your record of the number of particles producing single sprouts by the same amount. By this method your total number of seed particles in the three groups will always be 100, that is those remaining on the original blotter plus those on the blotter designated as singles, plus the number of seed particles discarded as producing two or more sprouts. This information is kept on a printed form provided for the purpose.

*Subsequent Examination.*—After the second examination proceed as in this examination in making all subsequent examinations.

The final examination will be made on the 11th day including the day the seed is placed in the germinator. This means there will be 9 sprout counts made in 9 consecutive days.

*The Record.*—When the final examination is made the following record shall be made:

1. *Percentage germinating seed particles.* This is the sum of the seed particles showing single and multiple sprouts divided by the total number of seed particles placed on the original blotters. That is, if 400-seed particles were used, divide the total germinating seed particles by 400 and multiply the result by 100. Example: if each of the 100-seed particles placed on the original 4 blotters germinated as follows: 85, 80, 78 and 86, there would be a total of 329 seed particles that sprouted. 400 seeds were used so $\frac{329 \times 100}{400} = 82.82$ percent germination.

In the event only 200 seed particles are used for the germination the 400 in the equation becomes 200.

The number of germinating seed particles must equal 100 minus the number of seed particles remaining on the blotter which held the original 100-seed particles. We have found that this double check on the germination prevents errors which easily occur.

2. *Percentage singles.* This is the number of seed particles remaining on the blotter designated "singles" (or shown by your report) expressed in percentage of the total number of germinating seed particles. That is the number of seed particles showing singles times 100 and divided by the total seed particles which have produced normal sprouts.

3. *Number of germinating seed particles per pound.*—This is the product of the number of seed particles per pound and the percentage germination.

In reporting the germination you will use the forms which have been provided for the purpose, giving all required information called for on the forms.

## Summary

The screening of the sample is to remove the small particles which should not be counted as seed particles. It is the intention that all particles remaining on the screen should be counted as seed particles.

Mold seldom bothers to any great extent. When it is severe the germination may be lowered considerably. Cleaning up the germinator and exposing the trays to direct sun light for several hours may remedy the cause. A Lignasan solution of 1 part Lignasan to 10,000 parts water in which the seed is soaked for 5 minutes just before germinating, seems to control mold without injury to the sprouts. The seed may be germinated without using depressions in the blotters however, the depressions help hold the seed particles in place and tend to reduce uncertainty in indentifying the seed particles from which some of the sprouts come.

# Some Field Conditions Which Influence Germination Technique

BION TOLMAN[1]

IT IS A WELL-ESTABLISHED fact that there are wide differences in the rate and total germination of some lots of sugar beet seed. It has been found that some lots of sugar beet seed contain substances in the corky seedball which are released during germination and have a toxic effect on the germinating seeds. The presence of these substances is reflected in delayed germination, darkening of sprouts, and lowered total germination percentage. It has been shown that these substances can be washed from the seedball as a part of the laboratory germination test, and that all interference with the laboratory test can thus be avoided. It has also been shown that these substances consist largely of nitrogenous compounds which during germination are broken down by enzematic activity to free-ammonia (1) (2) (3).[2]

This paper is a report on some field conditions which influence the amount of these toxic substances in the seedball.

### Effect of Fertilizer Practice

Sugar beets grown for seed respond greatly to nitrogen fertilization in most of the present seed-growing areas, and large amounts of nitrogen fertilizer are applied (4). Naturally the total amount applied, as well as the time of application, varies from one area to another and from one farm to another. That the fertilizer practice followed has an influence on the seed-germination procedure is apparent from the data presented in table 1. It is evident from the data that the late, heavy applications of nitrogen produced substances in the seedball which it was advantageous to remove by washing the seed prior to germination on blotters.

### Effect of Soil Conditions

In the seed-growing area in southern Utah, as well as in some other areas, sugar beet seed is sometimes grown on saline soils. These saline soils are of course high in soluble salts and frequently contain an abundance of nitrates In 1945, seed was obtained from three growers' fields in the vicinity of St. George, Utah, where the salt content of the soil was so high that not more than 10 to 25 percent of the plants survived. The germination of this seed was compared with seed from adjoining fields where the soil conditions were more normal. The results of these tests are given in table 2. It is evident from the data that soil conditions do markedly affect germination procedures.

### Discussion and Summary

Both late nitrogen applications and saline soil conditions have been shown to affect the concentration of substances in the seedball which inter-

[1]Agricultural Research Director, Utah-Idaho Sugar Company, Salt Lake City, Utah.
[2]The numbers in parentheses refer to literature cited.

fere with laboratory tests of sugar beet seed. Since these substances are water soluble they can be removed by washing the seed as a part of the germination procedure.

It is recognized that only a small portion of the seed produced in any one area in any one year may contain sufficient amounts of these substances to create a problem in germination. However, since in the seed testing laboratory it is not possible to foretell when one of these problem seedlots will be encountered, it would seem best to adopt a germination procedure which will adequately handle these seedlots. It has been demonstrated that washing the seed in running water for 2 hours prior to placing it in the blotters will not only prevent injury on problem lots, but will also increase the rate of germination on all seedlots.

**Table 1.**—The effect of washing sugar beet seed prior to the germination tests as influenced by certain field conditions.

| Conditions under which the seed was grown | Germination Percentage | | | |
|---|---|---|---|---|
| | Not Washed | | Washed 2 hours* | |
| | 4-day count | 14-day count | 4-day count | 14-day count |
| Effect of fertilizer treatment: | | | | |
| 1. Unfertilized check plots | 10 | 75 | 68 | 76 |
| 2. 600 pounds $(NH_4)_2SO_4$ May 15 | 8 | 65 | 70 | 75 |
| 3. 600 pounds $(NH_4)_2SO_4$ Oct. 15 | 20 | 76 | 73 | 77 |
| 4. 400 pounds treble-superphosphate | 18 | 76 | 70 | 77 |

**Table 2.**—Effect of salt content of soil.

| | | | | |
|---|---|---|---|---|
| A. High salinity—10 to 20 percent plant survival: | | | | |
| Field No. 1 | 8 | 67 | 86 | 93 |
| Field No. 2 | 11 | 70 | 84 | 85 |
| Field No. 3 | 15 | 79 | 81 | 85 |
| B. Low salinity—3 to 5 beets per 100 feet of row: | | | | |
| Field No. 1 | 23 | 75 | 74 | 78 |
| Field No. 2 | 57 | 84 | 79 | 83 |
| Field No. 3 | 31 | 74 | 68 | 73 |

*Seed washed in running water for 2 hours and air-dried for 24 hours.

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# The Effect of Pretreatment and Substrata on the Germination of Sugar Beet (Beta vulgaris L.) Seedballs

ALICE M. ANDERSEN[1]

IT HAS BEEN reported by some growers of sugar beet seed that lower germination results were obtained by seed laboratories on some lots of seed than had been obtained by the growers. These differences may result from the fact that the seedballs of certain lots, when tested between blotters at 20 degrees and 30 degrees centigrade alternating temperatures, produce some seedlings which are browned and are, therefore, considered abnormal and are not included with those considered to have germinated. Stout and Tolman (6)[2] in their investigation of the germination of sugar beet seedballs reported that the browning of some of the seedlings is due to ammonia released during germination from organic nitrogen compounds in the seedballs and that the browning can be overcome in general by washing the seedballs in running water for 2 hours or more, prior to placing them to germinate between blotters. The method stated in the Rules and Regulations under the Federal Seed Act (1) for the germination of garden beet seed is to soak the seed for 2 hours followed by a brief washing in running water prior to placing them to germinate between blotters at 20 degrees and 30 degrees centigrade alternating temperatures for a period of 14 days. The same provision is made for garden and sugar beet seed in the rules of the Association of Official Seed Analysts (2).

It was the purpose of this investigation to devote further study to such methods of germinating sugar beet seedballs under laboratory conditions as might give results more comparable with those obtained by the growers.

## Materials and Methods

Nine samples of sugar beet seedballs, from the 1947 crop, were used in these tests. These samples were selected because they produced a high proportion of browned seedlings. Five samples were grown near Phoenix, Arizona, 2 near Las Cruces, New Mexico, and 1 in Ogden Valley, Utah. Each sample was divided into 4 portions and treated as follows (a) untreated seedballs, (b) 12 replicates of 100 seedballs each soaked in 250 c.c. of water for 2 hours, then rinsed in running water, (c) 12 replicates of 100 seedballs each soaked in 250 c.c. of water for 4 hours, the water being changed after 2 hours and soaking continued for 2 more hours followed by rinsing in running water, (d) 12 replicates of 100 seedballs each washed in running water for 4 hours in the seed washer described by Gaddie (3).

[1]Seed Technologist, United States Department of Agriculture, Production and Marketing Administration, Grain Branch, Washington, D. C.

[2]Numbers in parentheses refer to literature cited.

Each portion of the treated seed was wrapped in several thicknesses of paper towels to remove the excess moisture.

Each sample was tested in three kinds of substrata as follows: (a) 8 replicates of 50 seeds each of the treated and untreated seedballs were placed between moistened blotters, (b) 4 replicates of 100 seedballs of the treated and untreated seed were placed in a mixture of sand and soil, at a planting depth ½ to ¾ inch, and (c) 4 replicates of 100 seedballs of the treated and untreated seed were placed on Kimpak (20-ply crepe paper). All tests were conducted at 20 degrees and 30 degrees centigrade alternating temperatures for a period of 14 days. The sand and soil tests were made in 1⅞x8½x8½-inch paraffined cardboard boxes containing partitions separating each seedball. The moisture of the sand and soil was not measured but enough water was added to make a loose ball when soil particles were pressed together. The Kimpak tests were made as follows: A moist blotter, 9x9½ inches, was placed on the tray; a 9x9½-inch piece of Kimpak was placed on the moistened blotter and 100 c.c. of water sprayed into the Kimpak; 100 seedballs were lightly pressed into the Kimpak with the counter, and the seedballs were covered with a slightly moistened blotter.

## Results

The average percentage of balls germinating free of browned seedlings was approximately equal on Kimpak and in soil and 28 percent higher than on blotters (table 1). The 3 pretreatments gave approximately equal results and were about 11 percent higher than the untreated seedballs when tested between blotters. There was no appreciable difference in the average germination results of treated and untreated seedballs when grown on Kimpak or a mixture of sand and soil (average of 2 percent or less in favor of the treated seedballs).

When the first count of the germinating seedballs in blotter tests was made the seedlings had no stem, practically no hypocotyl, but a well-developed root. However, in the soil and Kimpak tests the seedlings had a relatively long hypocotyl, as well as a well-developed root on the first count. Browning of the seedlings in the blotter tests varied from a stunting of the root hairs in the upper root-hair zone of the root, thus giving a ringed effect on the seedling, to a browning of the entire root, almost to the tip, and in some cases including the tip of the root. Browning of the seedlings in Kimpak and soil tests was mainly due to 1 or 2 very vigorous seedlings pushing the ball into the air and a smaller seedling with a browned root remained attached to the ball. However, in some cases the root of the seedling was browned under ground or in the Kimpak. The lesions on the hypocotyl of the seedling in the Kimpak or soil tests were in the form of cracks, brown streaks, or small round holes with a brown fringe. Seedlings with lesions on the hypocotyl were classified together with the browned roots in Kimpak tests as they were infrequent but separated from those with browned roots in the soil tests.

**Table 1.**—Average germination results obtained with 9 samples, from the current year's crop, of sugar beet seedballs sown from November 9 to December 5, 1947, at 20 degrees and 30 degrees centigrade alternating temperatures (8x50 or 4x100 seedballs used on each test).

| Pretreatments | Percentage of germination of sugar beet seedballs on designated substrata and indicated number of seedlings of balls and type of seedlings produced from balls, 14 days after sowing— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Between Blotters | | Kimpak | | | Soil and Sand | | | |
| | Balls having 1 or more seedlings | Balls having 1 or more seedlings | Balls having 1 or more seedlings | Balls having 2 or more seedlings | Total | Balls having 1 or more seedlings | Balls having 2 or more seedlings | | Total |
| | None of the seedlings were browned | Usually 1 or more seedlings were browned | None of the seedlings were browned | Usually only 1 seedling with lesions on the hypocotyl or browned root, and 1 or more normal seedlings | | None of the seedlings were browned | Usually only 1 seedling with lesions on the hypocotyl and 1 or more normal seedlings | Usually only 1 seedling with browned root and 1 or more normal seedlings | |
| Untreated seedballs | 48.28 | 41.67 | 85.53 | 3.50 | 89.03 | 81.36 | 3.11 | 3.50 | 87.97 |
| Seedballs soaked 2 hours | 58.14 | 34.44 | 86.44 | 2.25 | 88.69 | 82.86 | 4.33 | 3.03 | 90.22 |
| Seedballs soaked 4 hours | 60.31 | 32.67 | 85.81 | 2.31 | 88.11 | 83.36 | 3.92 | 3.06 | 90.33 |
| Seedballs washed in running water 4 hours | 59.22 | 34.17 | 86.78 | 3.14 | 89.92 | 83.81 | 4.25 | 2.67 | 90.72 |
| Average | 56.48 | 35.74 | 86.14 | 2.80 | 88.94 | 82.85 | 3.90 | 3.06 | 89.81 |

The tests made with treated and untreated seedballs in Kimpak gave an average germination of 86.14 percent seedballs of which none of the seedlings were browned or displayed lesions, and 2.80 percent of the balls contained 2 or more seedlings of which usually only 1 seedling had lesions on the hypocotyl or the root was browned and 1 or more were normal seedlings. This resulted in a total average of 88.9 percent germination on Kimpak. During the test period the substratum of the untreated seedballs was not as clean in appearance as the substratum of the treated balls. The untreated balls of some samples stained the Kimpak brown. The tests made with treated and untreated seedballs in a mixture of sand and soil gave an average of 82.85 percent germination of seedballs of which none of the seedlings showed lesions or browning, 3.9 percent of the balls contained 2 or more seedlings of which usually only 1 seedling had lesions on the hypocotyl and 1 or more were normal seedlings, and 3.06 percent of the balls contained 2 or more seedlings of which usually only 1 seedling was browned and 1 or more seedlings were normal. This resulted in a total germination of 89.81 percent balls on sand and soil. Seedballs pretreated by soaking for 2 or 4 hours and washed in running water for 4 hours and placed between blotters gave an average germination of 59.2 percent balls of which none of the seedlings were browned and 33.7 percent of the balls contained 1 or more seedlings of which 1 or more seedlings were browned. The untreated seedballs placed between blotters gave an average germination of 48.3 percent balls of which none of the seedlings were browned and 41.67 percent of the balls contained 1 or more seedlings of which 1 or more seedlings were browned.

The speed of germination was greater in blotter and Kimpak tests than in soil tests. The first count on blotters and Kimpak was made 3 or 4 days after sowing and in soil tests 6 or 7 days after sowing. The results of the blotter tests were not quite comparable with those obtained from Kimpak and soil. In the blotter tests the balls having 1 normal seedling and 1 browned seedling were not separated out and added to the total germination as they were in Kimpak and soil tests.

In general, the results reported herein with blotters and soil are in agreement with those of Stout and Tolman (6) except that they obtained a greater difference between treated and untreated seedballs tested between blotters (about 18.7 percent) than the writer obtained (about 11 percent). This difference may be due to the fact that Tolman and Stout washed the seedballs in running water for 24 hours while the writer washed the balls in running water for 4 hours, prior to testing between blotters. The difference between the treated seedballs and the untreated seedballs tested between blotters was noted in the severity of browning as well as on the percentage basis. The seedlings from the treated seedballs were considerably less browned than the seedlings from the untreated balls.

Rumbold (5) reported that sugar beet seedballs carried many fungus spores. The writer observed an abundance of *Alternaria* spores on many of the browned seedlings which were examined microscopically. *Rhizopus*

fruiting bodies were observed on a less number of browned seedlings and *Aspergillus* and *Fusarium* on an occasional browned seedling. From 45 plantings on agar made by Dr. Kotila (4) from the browned seedlings tested between blotters, 36 were identified as species of *Alternaria*, 4 as *Aspergillus*, 3 as bacteria, 1 as *Fusarium*, and 1 as *Rhizopus*. No conclusions on the cause of browning can be made from the tests completed at this time.

## Summary

The above preliminary results from 9 samples of sugar beet seedballs indicated that approximately equal germination results were obtained on Kimpak and soil. There was no appreciable difference in the germination results whether the seed was treated or untreated prior to testing on these 2 substrata. Seedballs pretreated by soaking for 2 or 4 hours and washed in running water for 4 hours, and tested between blotters gave higher results (percentage of balls producing seedlings free from browning) than untreated seedballs; none of the blotter tests gave as high germination results as Kimpak or soil tests.

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# Beet Seed Decortication with a Commercial Huller

R. S. Lambdin and Walter H. Buckingham[1]

Among the steps directed toward an ultimate mechanized program of sugar beet production, the processing of seed has become a necessity. The decortication of beet seed is a further step toward the goal of complete mechanization.

In April, 1947, it was decided that decorticated beet seed would be issued to growers for the ensuing crop year. Various manufacturers of seed-processing equipment were approached and samples of whole seed were submitted for processing. After the products obtained from each of the manufacturers' machines were analyzed, it was decided that the Forsberg Seed Huller would most closely meet the requirements. It must be realized that other machines also had possibilities, but time did not permit further experimentation with these machines.

The Forsberg Seed Huller is manufactured by Fred Forsberg and Son, Thief River Falls, Minnesota. This machine consists of a rubber-lined, tapered cylinder rotating in a rubber lined, tapered chamber. The seed follows a helical course through the anular space between cylinder and chamber. A 5-horsepower motor is required for the operation of this machine, which includes a suction fan and dust separator.

Decortication is accomplished by the action of the cylinder rubbing and rolling the seed against the outer liner. Radial clearance between the cylinder and liner ranges from zero to three quarters of an inch. Clearance is determined by an axial screw adjustment on the outer chamber.

Before entering the huller, the whole seed is first reduced by a shearing machine employing a steel cutting wheel with the shear bar clearance set between .110 inch and .164 inch, depending on the size of the individual seedlot being processed. From the shearing machine the seed passes into the Forsberg Seed Huller, then to the cleaner, screened in size between 7/64 inch and 10/64 inch, and finally to air classification.

The capacity of this machine varies from 300 to 700 pounds of whole seed per hour. This range is due to variation in size of seedballs of individual seedlots, speed, and clearance setting of the cylinder.

Heretofore, the capacity of the cleaner has been the limiting factor in determining the hourly rate of seed processed. This is no longer the case as the cleaner will handle the total capacity of the Forsberg Seed Huller.

The life of the rubber on the cylinder is approximately 40,000 pounds of seed, while the life of the rubber liners is approximately 150,000 pounds

[1]Spreckels Sugar Company.

of seed. Foreign articles, such as rocks, wire, etc., will cause sufficient damage to require the replacement of the above materials at more frequent intervals.

The speed of the cylinder apparently affects the germination. It was found that high speeds reduced germination whereas moderate speeds of 800 rpm or below gave no significant differences in germinations of the processed seed as compared to the original seed.

Overall recoveries have been slightly increased by the use of the Forsberg Huller. Here again, recoveries also vary with the individual seedlots.

From the results to date, it is evident that:

1. The hourly capacity of the cleaning and grading equipment has been greatly increased, thereby increasing the daily production of processed seed.

2. The resultant product is more dense and more spherical in shape than segmented seed or blends of screened and segmented seed.

3. Satisfactory stands have resulted from the use of this product in precision planters.

4. Operations to date have been commercially successful, yielding a product which has been acceptable to growers.

# Decorticated Seed—One Year's Experience

J. G. ENGLISH[1]

A SUGAR BEET seed decorticator was purchased in the spring of 1947 by The Great Western Sugar Company and installed at the Sterling, Colorado, factory seed-processing plant. As this machine was late in arriving, there was no opportunity for any primary experimenting in its operation and testing of the finished product. After planting season, a series of tests were decided upon and conducted. The results will be brought out later in this paper.

In order to keep abreast with new developments in seed processing, the management authorized the production of a quantity of decorticated seed for field experience in this type of seed.

Decorticated seed was issued to 12 Colorado factory districts, 6 in Nebraska, 2 in Wyoming and the Billings, Montana, area. In all, seed was furnished to 21 factory districts located in 4 states. Seventy-two planting trials were carried to conclusion, 43 in Colorado, 23 in Nebraska, and 6 in Montana.

In making these comparative plantings, decorticated seed with segmented seed, the standard segmented seed issued to growers was used as the check against the decorticated seed processed at Sterling. In these comparative plantings, three methods were used—strip planting, alternate rows of decorticated and segmented, or 2 rows of decorticated and 2 of segmented. Seeding was done with various standard makes of drills. Some flute-feed drills were used, but the majority of the plantings were with plate drills.

Decorticated seed was prepared from two types of Great Western seed: GW-85, a leafspot-resistant variety, and GW-268, a curly-top-resistant variety. The GW-85 decorticated seed was issued to all Colorado and Nebraska factories, and the GW-268 decorticated to the Billings, Montana, and Lovell, Wyoming, areas. All seed, both segmented and decorticated, processed for planting, was sized 7/64 inch to 10/64 inch. The GW-85 decorticated seed had a seedball count of 45,120 per pound, with 89 percent germination and 51 percent singles. The GW-268 decorticated seed had a seedball count of 49,640 per pound with 90 percent germination and 52 percent singles.

On the average the standard segmented seed used in the plantings carried about the same seedball count per pound as the decorticated seed.

As for germination and singles, the decorticated seed averaged about 5 percent higher in germination than the segmented, while the percentage

[1]Great Western Sugar Company.

of singles was about 10 percent higher in the segmented seed. The average of the results of these plantings are shown in tables 1 and 2.

**Table 1.**—Average field results of the 72 comparative plantings:

| Rate of seeding in pounds | Percent germination stand | Percent | | | Longest skip in inches |
|---|---|---|---|---|---|
| | | Singles | Doubles | Multiples | |
| **Decorticated Seed** | | | | | |
| 4.25 | 31.5 | 59.2 | 29.5 | 11.4 | 17 |
| **Segmented Seed** | | | | | |
| 4.17 | 24.0 | 66.5 | 26.0 | 7.5 | 24.5 |

**Table 2.**—Analysis of table 1—segmented seed as the check

| Rate of seeding in pounds | Percent germination stand | Percent | | | Longest skip in inches |
|---|---|---|---|---|---|
| | | Singles | Doubles | Multiples | |
| **Numerical Difference** | | | | | |
| + .08 | + 7.5 | − 7.3 | − 3.5 | 3.9 | − 7.5 |
| **Percentage Difference** | | | | | |
| +2.0 | +31.2 | −11.0 | −13.4 | −53.0 | −30.0 |

From the results shown in tables 1 and 2, decorticated seed produced a 31.2 percent greater emergence or germination stand. As for blanks or skips in rows, the decorticated seed averaged 7½ inches less in length than the check. The segmented seed gave a higher percentage of single plants and fewer doubles and multiples.

Two errors in these comparative plantings are evident in the planting procedure followed. First: the same variety of seed was used in only a few plantings, and second: the rates of seeding of the two types of processed seed were recorded in only a few plantings, as it was not foreseen at the time of planting that a possible difference in seeding rates was involved with a drill set for a particular rate of planting of segmented seed. Decorticated seed with certain drill setting planted somewhat heavier than the segmented.

However, seven plantings were made where actual seeding rates were recorded, and five known plantings where the same variety of seed was used. Tables 3 and 4 indicate the results of such trials.

**Table 3.**—Average field results of seven comparative plantings—actual seed rate recorded

| Rate of seeding in pounds | Percent germination stand | Percent | | | Longest skip in inches |
|---|---|---|---|---|---|
| | | Singles | Doubles | Multiples | |
| **Decorticated Seed** | | | | | |
| 5.0 | 29.3 | 56.3 | 31.7 | 12.5 | 17 |
| **Segmented Seed** | | | | | |
| 4.3 | 21.2 | 64.0 | 27.6 | 8.4 | 28 |

**Table 4.**—Average of field results of five comparative plantings using the same variety of seed—GW-85

| | | | | | |
|---|---|---|---|---|---|
| **Decorticated Seed** | | | | | |
| 4.1 | 23.9 | 67.6 | 26.4 | 5.8 | 24 |
| **Segmented Seed** | | | | | |
| 4.1 | 19.3 | 75.5 | 19.8 | 4.6 | 30 |

Although there were but few plantings involved in obtaining the results tabulated in tables 3 and 4, they indicate a trend in favor of decorticated seed as far as germination stand and length of skips in the row, both of which are important factors relative to the total plant population after thinning.

Further evidence of the trend in favor of decorticated seed is shown in table 5, which is a summary of seven plantings in the Sterling factory district. Table 5 also includes the seed-testing laboratory evaluation of the seed used with respect to germination, singles and seedballs per pound.

**Table 5.—Planting comparison with seed-testing laboratory evaluation of seed involved**

| Decorticated Seed | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Laboratory record of seed used: | | | —— Emergence Count—Percentage —— | | | | | |
| Germination | Singles | Seedballs per pound | Germination | Singles | Doubles | Multiples | Longest skip | Seed rate |
| 89.0 | 51.0 | 45,120 | 33.8 | 61.3 | 27.8 | 9.4 | 19 | 4.14 |
| **Segmented Seed** | | | | | | | | |
| 82.3 | 62.3 | 48,111 | 21.5 | 65.3 | 26.6 | 8.1 | 29 | 4.14 |

Results from controlled test plantings at the Longmont, Colorado, experimental station of The Great Western Sugar Company were not as favorable to the decorticated seed as the field plantings in the various factory districts.

Further field plantings are recommended with greater control of seeding rate and using the same variety of seed in the comparative plantings.

Many comments and observations from the various factory districts in reporting their results are interesting. A summary of these observations are:

1. Plants from decorticated seed were outstanding in appearance. Emergence appeared ahead of the standard seed.

2. Plants were larger and could be thinned several days ahead of segmented seed.

3. On any field it was easy to locate the decorticated seed plantings.

Early in this paper reference was made to a series of tests conducted with the decorticating unit. These tests were set up and conducted for the purpose of determining the proper setting of the decorticator that would give the best general results relative to recovery, germination and singleness, machine capacity and the mechanical operation of the equipment.

Operation of the unit previous to the running of the tests had indicated that from two different varieties of seed with the same unit setting, general results varied considerably. With this advance information, three types of seed were selected for testing, and each variety run through the test in an identical manner.

Characteristics of each variety of the whole-seed tested were determined beforehand. Seed was sized from plus 7/64 inch through plus 10/64

inch to determine the percentage of seed for each 64th inch. This divided the composite samples into four sized lots: + 7/64, + 8/64, + 9/64 and + 10/64. The characteristics of each group was then determined which covered germination, singles, seedballs per pound, and germinating seedballs per pound.

Because of the delicacy of adjustment of the unit, various settings of the burr mill and the polishing unit were decided upon before the testing began. These settings number 10 in all, which varied from .10 inch to .175 inch for the burr mill and .125 inch to .175 inch for the polishing or decorticating unit.

After dividing the composite sample of whole seed into the four sized lots mentioned, a study of their characteristics indicated that pre-screening before processing might be advantageous. This was tried, but proved the opposite and is not recommended. The resulting germinations and singles compared favorably, while the recoveries dropped off considerably.

Complete records were kept on all tests for each variety of seed tested, and tabulated for study.

In evaluating these tabulations, it was readily noted the maximum percentages of recovery, germination, and percentage singles, are not accomplished on the same burr mill and decorticator pad clearance. A graphical analysis of the various settings on the burr mill and decorticator pad clearances indicate that for the most inclusive results, a setting of .125 inch for each is desirable.

A summary of the noteworthy points of the tests are: 1. The specific gravity of decorticated seed is approximately 10 percent greater than segmented seed of the same variety.

2. No two types of seed react the same in processing.

3. If over 45 percent singles are desired, the recovery will drop proportionately. When high recovery or germination is desired, the percentage of singles must drop.

4. Decorticated seed germinates somewhat faster than segmented seed.

5. The capacity of the unit is approximately 500 pounds per hour at the .125-inch clearance setting for the burr mill and decorticating pad.

6. The machine should be re-designed for easier and more accurate setting of the burr mill and decorticating pad. Also a method or means should be devised to insure an even distribution of seed leaving the burr mill over the whole decorticating pad.

7. Pre-screening of the whole seed before decorticating is not recommended.

I herewith wish to credit Don Latta, assistant chemist at the Sterling factory, for the efficient and comprehensive manner in which he conducted the experiments with the decorticating machine.

# Two Seasons' Experience with Beet Seed Decorticating Equipment

R. J. TINGLEY[1]

ALL OF THE beet seed planted by growers for Holly Sugar Corporation in California, as well as that for Los Alamitos Sugar Company in Imperial Valley, is distributed by Holly from its Stockton headquarters. A high percentage of this seed, during the last two seasons, has been decorticated as one phase in the complete processing and preparation of seed for planting.

The equipment used for this work consists of two University of California beet seed decorticators built by the Blackwelder Manufacturing Company of Rio Vista, California. The original unit was constructed from plans worked out by the writer and the engineering staff of Blackwelder Manufacturing Company, using the ideas and general specifications of the pilot model developed by Professor Roy Bainer of the University of California at Davis.

Essentially, this machine consists of a vertical shaft on which is mounted a 10-inch diameter carborundum grinding-wheel revolving below a stationary steel burr plate, of the same diameter; and another vertical shaft on which is mounted a 20-inch diameter carborundum grinding-wheel revolving below a stationary rubber-faced plate. These shafts are driven from a single 5-horsepower electric motor by separate V-belt drives. They are so arranged that the sack-run beet seed is fed into the center of the steel burr plate, and after passing through it and around the grinding-wheel, it is collected into a funnel, thence by gravity into the center of the rubber-faced plate for final reduction in size.

The first one of these units was installed in the fall of 1946 and preliminary tests were run in cooperation with Professor Bainer to determine the best methods of operation, and to devise practical means of setting and adjusting the machine for the most efficient performance.

The second unit was installed in January, 1947, and both are now a part of the continuous seed-processing plant. The present procedure is to determine correct settings, of both the steel burr plate and the rubber plate, for each lot of seed by frequent checking of results with hand screens. The seed is all sized through 9/64-inch and over 7/64-inch round-hole screens, and is then further polished in a sandpaper-faced disc machine. The final grading is done over a "gravity-table" separator, to remove the desired fraction of light seed, determined by systematic cracking tests.

The original unit was equipped with a neoprene (synthetic rubber) plate which did not prove satisfactory. Subsequent plates were faced with

[1]District Agriculturist, Holly Sugar Corporation.

other grades of neoprene, natural rubber, and truck tread stock, but these materials lasted through only 100 to 200 bags of beet seed each. After our experience with these plates, and the experience gained by other sugar companies with similar materials, the Blackwelder Manufacturing Company secured a synthetic-rubber facing designated at No. 1285 which has proved very satisfactory, and the indicated life of this material will reduce the operating cost of the machines to a very reasonable figure. The first No. 1285 rubber plate actually processed 230,000 pounds of whole seed before it needed replacing. The second one, now being used daily, appears to be wearing even better, and it should handle even more seed than the first.

We are now using the second 20-inch diameter grinding wheel and indications are that it will outwear the first one by a wide margin. The 10-inch grinding wheel has been replaced, and the first steel burr plate has been changed to determine whether a new plate would increase the capacity even though the old one was not badly worn. No difference was noted in the hourly capacity with the new burr plate.

Up to December 31, 1947, these two decorticating units had processed 556,200 pounds of whole seed and produced 333,500 pounds of finished 7/64- to 9/64-inch seed. This represents an actual recovery of 60 percent of the original weight, including all of the experimental period of use, and also the elimination of about 10 percent of seed weight by the gravity table. Operations during the month of December, 1947, on U. S. 15 seed showed a net recovery of 62.74 percent of a total of 60,720 pounds of whole seed.

Some test runs have been made to determine the capacity of these units which indicated a rating of 400 to 600 pounds per hour, but our actual season's operations show a performance for the two units of about 500 pounds of whole seed or 300 pounds of processed seed per hour. Comparative germinations have shown that the decorticated seed usually has a germination of 3 to 6 percent lower than the original lot, and we plan to continue our work to see if this factor can be improved.

It is felt that the first half-million pounds of decorticated seed have contributed the preliminary information necessary to formulate plans for a sound, future seed-processing program. The experience in the field, as to rates of planting, distribution and emergence of decorticated seed, has amply justified our recommendation of this product over any other type of processed or graded seed.

# A Mechanical Spray Treater for Sugar Beet Seed

AUSTIN ARMER[1]

THE FUNGICIDE treating of sugar beet seed has heretofore been the task of the grower at planting time. The prevalent dust treatments were inconvenient to all growers and involved the hazard of skin and mucous membrane irritations, severe in the case of certain individuals. Haphazard treating methods often failed to distribute fungicide dusts throughout the seed mass, and subsequent handling was suspected of shaking off adhering dusts.

The foregoing comments point up the need for changes in treating methods. They are in effect a negative definition of a problem—a problem which can be defined in the following positive terms:

1. Beet seed should be treated prior to issuing to the grower.
2. Such treatment must not lose effectiveness or damage the seed after reasonable storage periods.
3. The fungicide should adhere firmly to the seed.
4. Each seed should receive a coating of fungicide.
5. The treated seed should not be irritating or toxic to those handling it during and after treatment.

The problem thus defined was solved by the coordinated effort of three groups. These were:

The Spreckels Sugar Company, Agricultural Engineering Department.

The University of California, Plant Pathology Division.

The U. S. Rubber Company, Naugatuck Chemical Division.

Preliminary discussions led to the tentative conclusions that the solution of the problem should involve:

1. The formulation of a liquid fungicide.
2. Spraying of the fungicide onto a seed mass in a high state of agitation.

## Selection of the Fungicide

The first phase of the problem was approached in the laboratory of the University of California Plant Pathology Division. The choice of the basic fungicide was made after determination of relative effectiveness and seed-keeping qualities of various commercial fungicides.

Organic mercury compounds proved most effective in controlling damping-off organisms, but showed evidence of reducing germination after relatively short storage periods.

[1]Agricultural Engineer, Spreckels Sugar Company.

The material most closely approaching the organic mercuries in protection and having no adverse effect on stored seed was Phygon (2, 3-Dichloro-1, 4-Naphthaquinone). This dust, in its commercial form, would not readily form a homogeneous suspension in water. The Naugatuck Chemical Division, however, succeeded in combining (with Phygon dust) wetting and stabilizing agents which yielded a semi-fluid paste readily miscible with additional water to any desired consistency.

### Selection of a Sticking Agent

The requirement of sticking the fungicide to the seed (to prevent separation subsequent to drying the sprayed seed) presented a problem which was solved in a rather informal manner. Whereas the market affords numerous water-soluble binders (Methyl Celulose, Sodium Alginate,

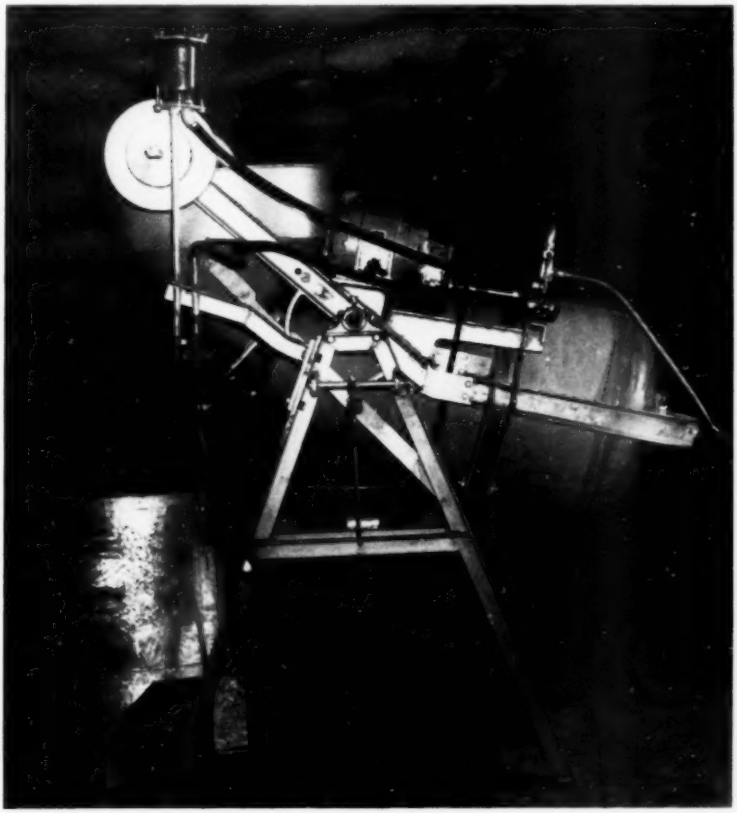

Figure 1.—A mechanical spray treater for sugar beet seed—Armer.

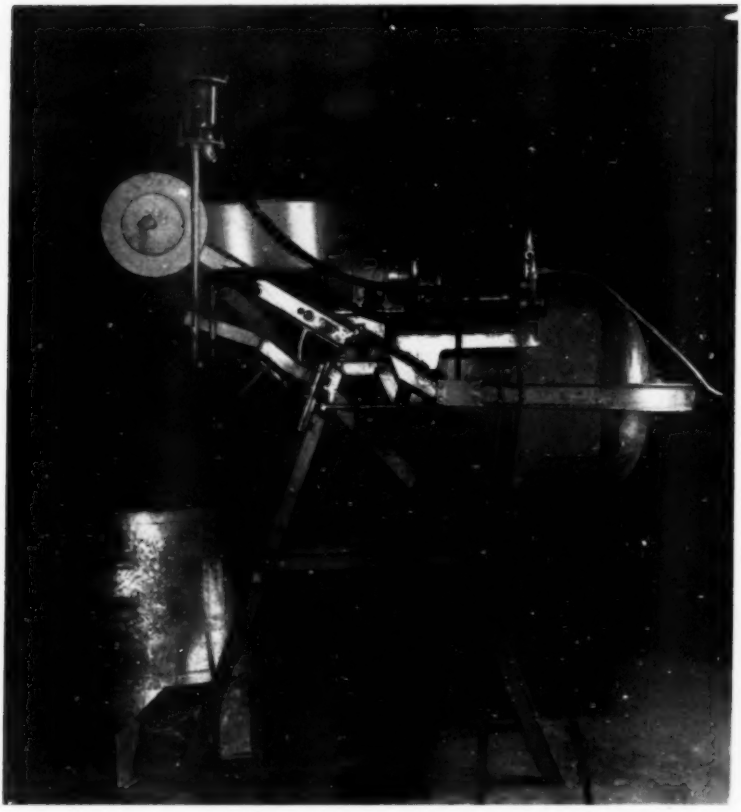

Figure 2.—A mechanical spray treater for sugar beet seed—Armer.

Vegetable gums, etc.), such materials lack the prime requisites of high adhesivity combined with high water permeability. The material selected to meet these requirements was discard sugar beet molasses. The choice of this readily obtainable material was fortuitous. It is of course highly adhesive ("sticky"), and is both water-soluble and water permeable. It is somewhat hygroscopic, but in the small quantities used, presents no problems arising from excess moisture pickup by the seed.

While molasses presents a splendid culture medium for molds (as abundantly proved when beet seed was treated with a plain molasses solution) the presence of the Phygon is insurance against mold growth over reasonable storage periods.

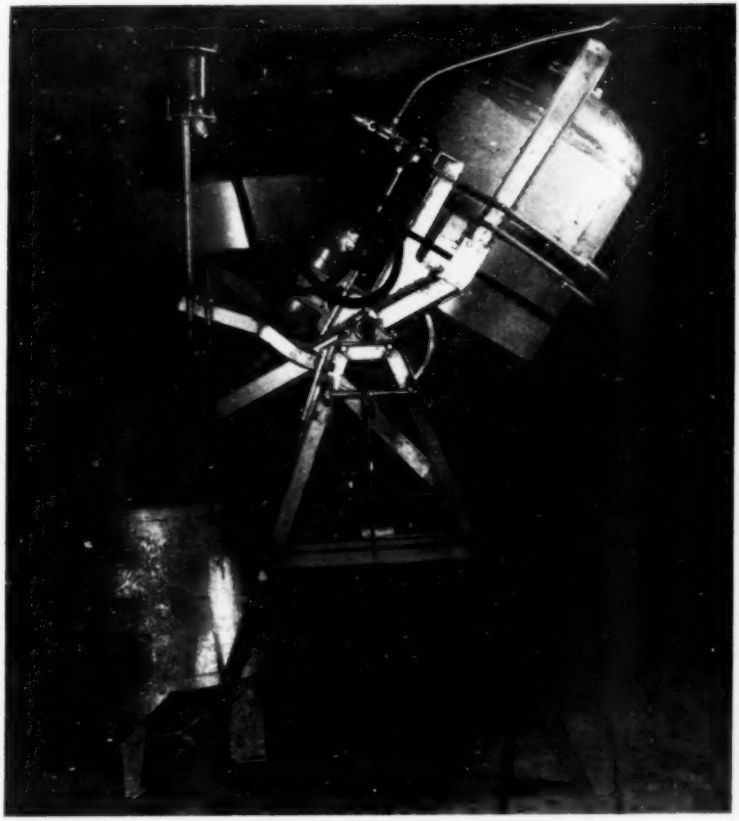

Figure 3.—A mechanical spray treater for sugar beet seed—Armer.

## Development of Spraying Equipment

In the laboratory phases of the spray-treating development, a small cement mixer was used to contain and agitate the seed batch while subjecting it to the spray action. While yielding a product which showed up well in comparison to dust-treated seed, it was evident that such a crude agitating device fell far short of the requirement *that each seed be presented at least once to the spray stream.* Two devices in common use suggested the design eventually adopted. These were the sugar dryer and rice polisher. Both are drums rotating on axes inclined slightly from horizontal; having vanes which pick up a portion of the contents; and (as rotation proceeds) drop this portion progressively in a thin, falling sheet.

The inclined axis is not conducive to the formation of uniform, thin, falling sheets. It is a requirement for continuous feed and discharge. It was therefore determined that a batch mixer, holding 50 pounds of seed, would fit well into the seed-processing cycle, since bagging of the seed would follow immediately after treating.

The design data for a desirable treating machine could then be outlined as follows:

1. A cylindrical, inside-vaned drum rotating on a horizontal axis.
2. Spray nozzles within the drum, fixed in space and located so as to spray the falling sheets of seed.
3. Means for metering the volume (or weight) of spray material automatically released during each refilling of the drum with seed.
4. Means for forcibly discharging the spray material through the nozzles.
5. Means for storing and agitating a supply of fungicide suspension.
6. Means for storing and releasing a charge of seed into the drum.
7. Means for discharging the contents of the drum into a bag.
8. A general arrangement of components permitting the receiving of seed at a minimum height and discharging at a maximum height.

These design data were worked up into drawings of several possible mechanisms, and the simplest of these designs adopted for refinement and construction.

Two machines as illustrated were put into service and have performed in a highly acceptable manner. The cycle of operation may be briefed thus:

| *Operation* | *Time Required* |
|---|---|
| 1. Swing drum to charge position and admit seed. (Figure 1) | 10 seconds |
| 2. Swing drum to horizontal position and turn on spray valve. (Figure 2) | 5 seconds |
| 3. Allow one unit (about 1 quart) of spray material to discharge into drum | 20 seconds |
| 4. Allow drum to rotate after spray stops (to clean up and dry interior of drum) | 30 seconds |
| 5. Discharge contents of drum to bag. (Figure 3) | 10 seconds |
| Total time for one cycle | 75 seconds |

It should be noted that the spray valve is a pair of three-way cocks so arranged as to pump spray material from the agitator-storage tank into an elevated measuring chamber which overflows (when full) back to the storage tank. Thus, during the entire cycle, except while spraying, the measuring chamber is kept full or overflowing, and is at any time thereafter ready to discharge its measured contents. Figure 4 illustrates individual seeds, sack-run, decorticated and spray treated, respectively.

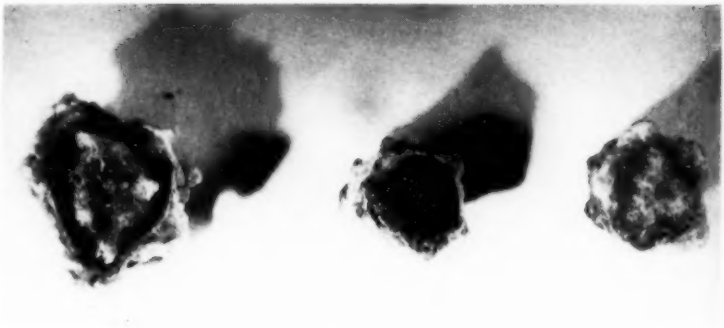

Figure 4.

## Conclusions

The method and equipment described is operating on a commercial scale and is delivering a seed having:

1. Satisfactory resistance to damping-off organisms.
2. Freedom from irritation or toxicity to either processing or planting personnel.
3. Satisfactory storage qualities.
4. No discernible stickiness or dampness.

The development of methods and equipment leading to these results exemplifies the rapid and direct solution of a problem made possible by the close cooperation of specialists in plant pathology, fungicide chemistry and machine design. This development was therefore a cooperative engineering program aimed at a quick commercial solution to a problem and necessarily by-passed many research phases. Methodical research therefore holds the answers to such questions as:

1. How uniformly is each seed coated?
2. How necessary to field protection is uniform coating and dosage of each seed?

# Experience with Decorticated Seed on 30,000 Acres

ROBERT C. BROWN[1]

APPROXIMATELY 30,000 acres of sugar beets were planted in the Imperial Valley in 1947 with a new type of seed. The change from sheared seed, which had been used previously, was made because of the results of tests conducted in 1946.

In the search for better ways to process sugar beet seed, a new method has been developed, which is called seed decortication, and which shows much promise. Our aim in processing seed is to give the grower a product that will lessen his labor, and still give him a normal stand of beets at a reasonable cost. The decorticating process is so recent a development that it has not been thoroughly tested in all areas as yet. The tests to date, however, have been encouraging.

In the decorticating process, whole seed is worn to the size desired instead of being broken into segments as is the case in seed-shearing operations. The new product is rounder and smoother than sheared seed, thus making it more adaptable for use in precision planters. Decorticating is less severe on seed than shearing, which accounts for less seed damage and fewer abnormal plants. In field comparison, decorticated seed appears to have more vigor in the early stages of growth. Upon observation of the seedlings, there appears to be less damage to seed leaves in decorticated seed as compared with heavy seed leaf damage in sheared seed. This type of damage may have a much greater effect on young plants than we realize. In the Imperial Valley the difference in vigor between the two types of seed is quite definite in the early stages of plant growth.

Taking the same lot of seed and processing it by both methods, 7/64 inch to 9/64 inch in size, it was found that the decorticated seed was reduced to 1.6 seedlings per viable seed unit as compared to 1.13 seedlings per viable seed unit in the shearing process. Under good germinating conditions, field emergence for both types of seed is about the same. Under poorer germinating conditions, it was noticed that we produced more inches of single plants from decorticated seed than we did from sheared seed. It was also noted that the percentage of inches containing single plants increased with a decrease in field emergence. In other words, it appears that the more severe the field conditions are, the better the performance of decorticated seed.

In the Imperial Valley, as well as other beet-growing areas, only a very small percentage of the acreage has the physical requirements for ideal germinating conditions. It is up to us to recommend the type of seed that

[1]District Agriculturist, Holly Sugar Corporation, Brawley, California.

gives the best results for general local conditions. Since decorticated seed, with 1.6 seedlings per viable seed unit as compared to 1.1 in sheared seed, seems to have been giving us better results in general field performance, then perhaps our breeding program in search of a single-germ seed may not be the answer to a beet grower's dream, and seed with a uniform factor of doubleness may come closer to solving the problem. Charles E. Cormany[2] made an interesting test in regard to this situation. He picked out, under a magnifying glass, seed that contained single-seed locules, double locules and triple locules. These were field planted by hand, and the results as shown in table 1 seem to indicate that double seed is the most desirable.

**Table 1.—Summary of stand counts by hills on Single-, double- and multiple-germed segmented seed. Beet Seed Breeding Department—Planting at Sheridan, 1946.**

| Variety MW4B-44 | | | | | |
|---|---|---|---|---|---|
| **Treatment** | **Percent singles** | **Percent doubles** | **Percent multiples** | **Percent hills containing seedlings** | **Total number plants Basis 100 hills** |
| Singles | 26.75 | 1.75 | 0.25 | 28.75 | 31.00 |
| Doubles | 22.75 | 15.25 | 1.75 | 39.75 | 58.50 |
| Multiples | 17.25 | 12.50 | 4.75 | 34.50 | 58.00 |

Table 1 shows that the total number of plants germinated from single locules was only 31 percent, as against 58 percent from double-locule seed. The distribution factor for double seed is 38 percent better than single seed. In the case of triple-locule seed, the total number of plants is about the same as double-locule seed. The triple-locule seed was down on singles, not bad on doubles, but produced more triples and showed poorer distribution than double seed.

Further consideration of the comparative merits of decorticated and sheared seeds must include the stands produced after thinning. Table 2 shows a comparison of decorticated seed with sheared seed in Imperial Valley, in respect to stand count after thinning. Professor Roy Bainer[3] mentioned the fact that decorticated-seed plantings appeared to produce fewer skips than sheared-seed plantings. With this thought in mind, we tried to evaluate the degree of loss from skips in the stand. We made a series of four tests, in widely separated areas in the Imperial Valley, on various types of land. One-third-acre test plots were marked off and planted in commercial beet fields. In our 34-inch row spacing, we require an average of 150 well-spaced beets per 100 feet of row length for maximum production. We estimate that skips of less than 12 inches are negligible, while skips of 12 inches or longer will lessen production. With the above thought in mind, we averaged the number of skips 12 inches or over for each type of seed. The results of the four plantings showed an average of twelve 12-inch skips in the decorticated seed and 22½ skips in the sheared seed. In the stand count per 100 feet, the average number of beets from decorticated seed was higher than the average number from sheared seed.

[2]Chief Agronomist, Holly Sugar Corporation, Sheridan, Wyoming.
[3]Agricultural Engineer, California Agricultural Experiment Station, Davis, California.

Both types of seed produced enough beets per 100 feet, but evaluating the stand by the skips, decorticated seed showed an 88-percent stand as against a 77-percent stand for sheared seed.

Table 2.—Decorticated seed plantings, Imperial Valley.

| Cobbley Plantrol Planters—13 Cells per Foot<br>Row Spacing—34 inches U. S. 15 Seed | | | | |
|---|---|---|---|---|
| **Seed** | **Size** | **Soil type** | **12-inch gaps per 100 feet** | **Stand count per 100 feet** |
| | | **Brown & Simons** | | |
| Decorticated | 7-9 | medium | 2 | 161 |
| Sheared | 7-9 | medium | 7 | 157 |
| | | **R. B. Wilson** | | |
| Decorticated | 7-9 | medium | 21 | 131 |
| Sheared | 7-9 | medium | 28 | 128 |
| | | **Rutherford & Alvarez** | | |
| Decorticated | 7-9 | heavy | 7 | 190 |
| Sheared | 7-9 | heavy | 28 | 168 |
| | | **Harry C. Smith** | | |
| Decorticated | 7-9 | light | 18 | 148 |
| Sheared | 7-9 | light | 23 | 144 |
| Average Decorticated | | | 12.0 | 157 |
| Average Sheared | | | 22.5 | 149 |

During the 1947 planting season, we planted our entire acreage with decorticated seed, and the results so far have been most gratifying. Out of 28,400 acres originally planted, we have replanted 418 acres and have abandoned 540 acres. In no case could the abandonment or replanting be attributed to failure of the seed. The percentage of replanted and abandoned acres comes to only .0303 of the total, which is quite remarkable when we consider that a large number of growers are raising their first beets.

Our average rate of seeding was 4.6 pounds of decorticated seed per acre, and more than 80 percent of our acreage was planted with precision-type planters. Stands were generally good and a normal crop of beets is in evidence. We believe that it will be shown by our 1947 sugar beet crop that decorticated seed is better adapted to Imperial Valley conditions than is sheared seed.

# Stand Count Comparisons of Segmented and Decorticated Sugar Beet Seed

C. E. Cormany and Donald F. Peterson[1]

The whole field of sugar beet seed processing is in its infancy. Improvements in the methods of processing sugar beet seed and also in the processed seed itself can be expected from time to time.

One of the most recent developments is the mechanics of "decorticating" seed with the production of so-called "decorticated" seed. The advantages claimed for this type of processed sugar beet seed are that (1) the germs in the seedball units are not injured as much as with shearing, (2) the finished product is less angular, viz., there are fewer "lense shaped" seed units, and therefore feeds through the planter better, (3) the accumulation of dust or chaff in the seed bag in which the grower receives his seed is less than for sheared seed, (4) the pre-thinning stands of beet plants are better than for sheared seed, (5) the pre-thinned plants are more vigorous, (6) the recovery at processing is greater than for sheared seed.

This paper will present brief data on the comparisons of pre-thinning stands of decorticated and segmented seed in five locations in the Rocky Mountain area of the United States.

The sheared seed and decorticated seed were graded through a 10/64-inch round hole screen and retained on a 7/64-inch round hole screen. The seed in each location was planted with the same drill with the same plates for both kinds of seed, and the actual weight of seed planted was known. With the weight of seed planted, number of seed units per pound, and total row length it was possible to accurately determine the number of seed units planted per foot. With germination records on all seed used the theoretical germination was easily computed. (See table 1.)

The results of these trials, conducted in the spring of 1947, are shown in table 1.

The average rate of planting per acre by weight of seed alone was 12 percent more for decorticated than for segmented, but the actual number of seed units per unit-of-row length was practically the same for both kinds of seed. The weight per bushel of the decorticated seed was 34 pounds with 37,694 seed units per pound, whereas for the segmented seed it was 27.5 pounds with 44,320 seed units per pound.

Emergence varied considerably among the five factory areas. Decorticated seed averaged 7 percent greater emergence for all tests. In the four areas where the variety MW 4 B was used, decorticated seed averaged less than 1 percent higher in emergence, whereas at Grand Junction,

[1]Chief Agronomist and Plant Breeder, respectively, Holly Sugar Corporation, Sheridan, Wyoming.

Table 1.—Comparison of pre-thinning stand counts on decorticated and segmented seed plantings under field conditions in 1947*

| Location of test | Processing* | Percent germination | Seed units planted per foot | Inches per foot containing plants | | Percent of inches of row containing | | | Percent of potential Emergence |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Theoretical | Actual | Singles | Doubles | Multiples | |
| Sidney, Mont. | Dec. | 81 | 8.1 | 6.56 | 4.25 | 54.6 | 37.9 | 7.5 | 64.8 |
| | Seg. | 82 | 8.5 | 6.97 | 3.80 | 56.3 | 38.4 | 5.3 | 54.5 |
| Worland, Wyo. | Dec. | 81 | 7.9 | 6.40 | 2.06 | 63.6 | 31.5 | 4.9 | 32.2 |
| | Seg. | 82 | 6.7 | 5.49 | 1.90 | 77.4 | 20.0 | 2.6 | 34.6 |
| Sheridan, Wyo. | Dec. | 81 | 6.5 | 5.26 | 2.52 | 62.3 | 30.2 | 7.5 | 47.9 |
| | Seg. | 82 | 5.5 | 4.51 | 2.52 | 68.2 | 26.6 | 5.2 | 55.9 |
| Swink, Colo. | Dec. | 81 | 7.4 | 5.99 | 1.95 | 58.5 | 35.4 | 6.1 | 32.6 |
| | Seg. | 82 | 7.1 | 5.82 | 1.74 | 74.7 | 22.4 | 2.9 | 29.9 |
| Grand Junction, Colo. | Dec. | 84 | 9.1 | 7.64 | 4.09 | 54.5 | 33.0 | 12.5 | 53.5 |
| | Seg. | 71 | 12.2 | 8.66 | 2.51 | 77.3 | 19.9 | 2.8 | 29.0 |
| Average | Dec. | | 7.8 | 6.37 | 2.97 | 57.6 | 34.0 | 8.4 | 46.6 |
| | Seg. | | 8.0 | 6.29 | 2.49 | 68.7 | 27.3 | 4.0 | 39.6 |

*Variety US 22 used at Grand Junction; other locations MW 4B.

Colorado, decorticated seed was 24.5 percent better in emergence where variety US 22 was used. It is entirely possible that varietal differences may be encountered in the decorticating process.

More singles are expected from segmented seed, and this was true in these tests. The segmented had 11 percent more singles. The decorticated seed produced 6.7 percent more doubles and 4.40 percent more multiples.

Under the condition of these tests decorticated seed was superior to segmented seed in pre-thinning stand counts.

Visual vigor readings, using an arbitrary standard, indicated a slightly higher score for the decorticated seed.

Little difference was expected in after-thinning stand counts, and such was the case. The decorticated plantings showed 2 percent more plant containing feet and 4 percent more plants per 100 foot of row. Summary of the after-thinning data is shown in table 2.

**Table 2.**—Average comparison of after-thinning stand counts of decorticated and segmented seed plantings at five locations under field conditions in 1947.

| Type of seed | Average total feet of row containing plants | Average plants per 100 feet of row | | | | Average total number gaps 12" or more in row |
|---|---|---|---|---|---|---|
| | | Singles | Doubles | Multiples | Total | |
| Decorticated | 80.02 | 66.59 | 12.75 | .68 | 94.17 | 12.96 |
| Segmented | 78.34 | 67.46 | 10.22 | .66 | 89.83 | 14.52 |

A total of 577 stand count comparisons of the two types of seed were made in commercial fields in seven factory districts in the mountain area. The decorticated seed averaged 3.75 percent better in pre-thinning stand counts and 6 percent better in after-thinning counts than the segmented.

# Present Status of Sugar Beet Seed Processing

ROY BAINER[1]

FULLY 90 PERCENT of the 1947-1948 United States sugar beet crop was planted with processed seed. Early beet-seed processing investigations started in 1941 at the University of California with the development of equipment for segmenting seed. (1) (2)[2]

During the first year or two after the adoption of segmented seed, growers and processors alike were of the opinion that the goal in seed processing was the production of single-germ units. Several processors succeeded in producing and marketing a product that was made up of 85 to 90 percent single-germ units. A final product having a germination of 85 to 90 percent was made possible through the use of gravity table separators and aspirators. However, the production of single-germ seed of high germination resulted in low recoveries. Often-times, 100 pounds of whole seed yielded only 30 pounds of processed seed, of which 5 to 10 percent produced abnormal seedlings.

Irregularities in field stands planted with segmented seed were attributed to poor planter metering and placement with the result that requests were made for improved planting equipment. Intensive laboratory and field studies made at the California and Colorado Experiment Stations assisted in making improved planting equipment (3) available—equipment capable of metering and placing one seed at a time with reasonable accuracy.

While the use of improved planting equipment improved regularity of stands planted with segmented seed having a high single-germ count, it did not give the final answer desired. When seed containing as many as 1.4 seedlings per viable seed unit was used, more uniform stands resulted with a surprisingly high percentage of beet-containing inches with single seedlings. Under a field emergence of 54 percent, 70 percent of the inches containing plants had singles.

By 1946, several of the seed processors were preparing and issuing seed that ran as high as 40 percent doubles (1.4 seedlings per viable seedball). In general, more uniform seedling stands resulted from the use of the seed. While the percentages of singles dropped somewhat, the advantage in labor saving did not decrease in the same ratio. Recoveries of seed in the processing plants were also improved.

Further research work relative to seed processing produced two new processes; namely, burr reduction and decortication. (4) Later, the two processes were combined and put into commercial use. With the exception of beets grown for one company, practically the entire 1948 sugar beet crop in California was planted for the first time with seed processed with this new equipment. The above-mentioned company used a commercial seed

[1]Agricultural Engineer, University of California, Davis, California.
[2]The numbers in parentheses refer to literature cited.

huller for decorticating after first running the seed through a segmenter with a wide setting of the shear bar.

The equipment, figures 1 and 2, used for preparing the seed consists of a 1½ by 10-inch carborundum stone (Norton 37C24QV) and a 10-inch burr plate (Letz AA230) for the first reduction stage. The second stage consists of a 1 by 20-inch carborundum stone and a neoprene pressure pad 20 inches in diameter. The stones are mounted on vertical shafts and driven at a peripheral speed of 2,000 fpm through V belts from a common electric motor. Clearances between the stones and the burr and pressure pad are maintained at approximately 0.125 inch. A slight taper (⅛ inch per inch) halfway from the center to the outer edge of the pressure pad facilitates the feeding of seed. It was also found necessary to grind the corner, at the outer periphery of the pressure pad, at an angle of about 45 degrees in order to prevent the formation of a lip as the pad became worn. In operation the pressure of the seed against the pad caused the surface to stretch slightly beyond the edges of the stone which in turn reduced the wear on this small section, allowing the formation of an overhanging lip of neoprene which

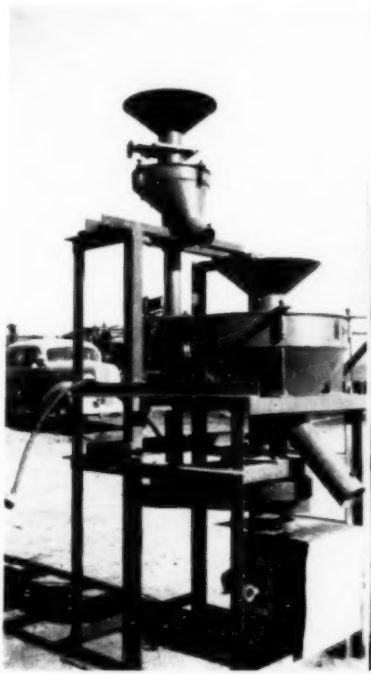

Figure 1.—Commercial seed-processing unit.
Figure 2.—Commercial seed-processing unit opened to show the two stones, burr plate and pressure pad.

prevented accurate adjustment between the plate and the stone when the machine was idle. Both units are enclosed in steel cases with hoppered bottoms. The inner wall of the case surrounding the burr and pressure pad is lined with a ½-inch layer of sponge rubber to reduce the shock to the seed as it leaves the stone and hits the wall. The seed is fed to the center of the wheels from the hoppers above. The rate of flow is regulated by an adjustable gate between the hopper and the burr reduction unit.

During operation, sack-run whole seed is fed directly from the hopper (figure 1) through the center of the burr plate to the center of the revolving stone. The seed is moved between the face of the stone and the burr plate by centrifugal force. This first stage operates as a pre-breaker, reducing the size of the larger seedballs to the extent that the entire sample will pass through a 13/64-inch screen. The output of the burr reduction unit feeds by gravity into the hopper above the decorticating unit. The partially reduced seed then passes between the neoprene pressure pad and the revolving stone with the result that most of the corky material is rubbed off, and many of the locules are opened, thereby releasing many of the germs. The discharge from this unit consists mainly of one- and two-germ seed pieces and a large volume of corky material removed from the seed. The seed is reduced to about 10/64-inch in size. The capacities of the 10-inch burr reduction unit and the 20-inch decorticating unit are comparable; namely, approximately 500 pounds of whole seed per hour.

Following the decorticating operation, the seed is cleaned and graded. The light, corky material, as well as the lighter seed pieces, can be readily removed through the use of an aspirator designed by Austin A. Armer.[3] In the majority of cases, final grading has been done between 10/64- and 7/64-inch round-hole screens. The exceptions have been to grade to 9-7 or 12-9 sizes. In the latter case, very little decortication was accomplished. Some processors use a gravity table separator for the final grading on the basis of density.

The results of preliminary runs with the machine are shown in table 1. Five lots of seed of 1,000 pounds each were processed to the 9-7 size. Final grading was done on a gravity table. One hundred pounds of whole seed having a germination of 90.4 percent and a seedling count of 1.9 produced 56 pounds of processed seed with a germination of 89.6 percent and a seedling count of 1.6. The recovery on the basis of total seed units and viable seed units amounted to 84.4 and 83.7 percent, respectively. Further experience with this unit brought the recovery up to 60 percent by weight during the production of some 330,000 pounds of finished seed. Recoveries, by weight, of 65 to 70 percent are accomplished when the seed is reduced only to the 10-7 size.

[3]Formerly Associate in Agricultural Engineering, University of California; now Agricultural Engineer, Spreckels Sugar Company.

Seed processed in the above manner is superior to segmented seed in every respect except one; namely, singleness of germ, and this may prove to be an advantage. Comparative laboratory germination trials showed that seed processed by segmentation produced 1.2 to 1.4 seedlings per viable seed unit as compared to 1.5 to 1.6 for decorticated seed. The size of the seed was the same for both processing methods. This was fortunate in that equipment adapted to plant one would handle the other. In addition to a marked improvement in the recovery of seed during the new processing operations, the new product germinated equally as well as the original seed, was less sensitive to planting depths and did not produce as many abnormal plants. The processed seed has a smoother exterior than either segmented or whole seed and is more dense, which improves its flow through planting equipment.

**Table 1.—An analysis of preliminary runs consisting of 5-1,000 pound samples processed by combination of burr reduction and decortication. Seed reduced to 9-7 size.**

| Germination | | Seedlings per seed unit | | | | Seedlings per viable unit | Seeds per pound | Percent recovery | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Normal | Abnormal | 1 | 2 | 3 | 4 | | | Weight | Number | units |
| | | | | | Whole | | | | | |
| 90.4 | | 25.0 | 47.3 | 15.3 | 2.8 | 1.9 | 28216 | 100 | 100 | 100 |
| | | | | | Decorticated | | | | | |
| 89.6 | 1.9 | 35.8 | 48.8 | 4.8 | 0.2 | 1.6 | 42492 | 56.0 | 84.4 | 83.7 |

Relative rates of emergence of whole, segmented and decorticated seed were determined under various soil-mositure and temperature condtions. (5) The only real differences came at the lower levels of soil moisture. For example, the test run at 9 percent soil moisture and 50 degrees F. showed germination of decorticated seed 56 percent complete at the end of 20 days as compared to 20 percent for segmented seed and 14 percent for whole. Such differences could mean the difference in obtaining a stand of beets under unfavorable germination conditions.

Sugar beet seed processing should be considered only as a temporary measure to overcome some of the obstacles of using whole ungraded beet seed. Plant breeders are making definite progress toward the production of single- and double-germ seed. In the light of tests reported in this paper and those conducted in other sections of the country, it is evident that industry does not want single-germ seed unless it can be developed to the point of giving better field emergence. The chief reason for most seed processing is to prepare the seed for precision planting. For the time being, at least, it is necessary to reduce the size of the seed to the point where its variation does not exceed 3/64-inch if available precision planting equipment is to be used. No doubt, some polishing will still be required when the plant breeders are ready to release the new seed in order to facilitate precision planting. This could be accomplished through a light decortication.

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# Comparison of Clipper and Eureka Cleaning Mills on Sizing of Segmented Beet Seed

C. W. DOXTATOR[1]

A PRECISION planting job in a beet grower's field is not only dependent on the type of drill used, but also on the size of the processed seed. New beet drills capable of planting beet seed quite uniformly are now available and therefore accurate grading, or sizing, of seed is more important than in earlier years. This paper reports the results of seed-sizing experiments, using two standard cleaners, the Eureka No. 7 and the No. 68D clipper.[2]

## Characteristics of 7/64-10/64-Inch Segmented Seed

In 1945 all segmented seed produced at Rocky Ford, Colorado, was cleaned and sized over a Eureka No. 7 seed cleaner. In 1946, a No. 68D Clipper cleaner was obtained, and segmented seed was cleaned over this mill; and the Eureka No. 7 was used to clean and size whole seed prior to segmentation. Late in 1946 it was observed that the number of seedballs per pound had dropped to approximately 33,000, whereas in 1945 the number of seedballs per pound ranged from 43,000 to 47,000. Since all seed had been sized over mills equipped with 7/64-inch and 10/64-inch round-hole screens, it was first assumed that the reduction in number of seeds per pound was due to unusually well-filled germs in the whole seed being processed. Later, however, it was apparent by ordinary inspection that the seed cleaned by the Clipper cleaner was larger than that formerly obtained from the Eureka. Characteristics of two representative seedlots, one from each cleaning mill, are given in table 1.

**Table 1.—Characteristics of segmented seed obtained from the No. 7 Eureka and from the 68D Clipper mills.**

| Characteristics | | Eureka No. 7 Mill Lot 3 | 68D Clipper Mill Lot 46 |
|---|---|---|---|
| Seed size | | 7-10/64" | 7-10/64" |
| Number of seedballs per pound | | 43,324 | 34,105 |
| Percent germination | | 84.5 | 95.5 |
| Number of viable seedballs per pound | | 36,608 | 32,570 |
| Sprout count per 100 seeds tested: | | | |
| | Singles | 44.0 | 29.0 |
| | Doubles | 38.5 | 54.0 |
| | Triples | 2.0 | 12.5 |
| | Total | 127.0 | 174.5 |
| Percent recovery | | 60.5 | 61.1 |

Germination percentage was much higher in seed cleaned over the 68D Clipper, indicating that this seed had less barren-seed segments, and therefore would be expected to have fewer segments per pound. Due to a larger number of seed segments per pound there were more viable seeds per pound in seed cleaned over the Eureka No. 7, which was an indication that Eureka-cleaned seed was smaller in size.

[1]Plant Breeder, American Crystal Sugar Company, Rocky Ford, Colorado.

[2]Eureka seed cleaners are manufactured by S. Howes & Co., Silver Creek, New York; and Clipper cleaners by the A. T. Ferrell Co., Saginaw, Michigan.

## Comparison of Seed Cleaning Mills

An adequate quantity of seed was available of Mill Lot No. 46, which had been cleaned and sized over the 68D Clipper, and this seed was used for a comparison of cleaning mills. For a check on Clipper seed sizing, 1,000 pounds was run over the Eureka cleaner. Another 1,000 pounds was rerun over the 68D Clipper. A third run of 1,000 pounds was made over the 68D Clipper, equipped with 7/64-inch and 9/64-inch round-hole screens. The results are given in table 2.

**Table 2.**—Comparison of the 68D Clipper and the No. 7 Eureka in seed sizing, using segmented seed originally sized 7/64 to 10/64 inch by the Clipper.

| Size of Seed | Proportion in pounds of seed obtained from: 68D Clipper equipped with: 7/64 & 10/64 RH screens | 68D Clipper equipped with: 7/64 & 9/64 RH screens | Eureka No. 7 equipped with: 7/64 & 10/64 RH screens |
|---|---|---|---|
| 7/64" to 9/64" | --- | 278 | --- |
| Above 9/64" | --- | 692 | --- |
| 7/64" to 10/64" | 968 | --- | 695 |
| Above 10/64" | 10 | --- | 288 |
| Below 7/64" | 14 | 21 | 10 |
| Dust (by difference) | 8 | 9 | 7 |
| Total | 1,000 | 1,000 | 1,000 |

These results indicated that the 68D Clipper had done an accurate job of sizing the seedlot to 7/64-10/64 inch in the original cleaning, since only 10 pounds, or 1 percent, went over the 10/64-inch screen in the rerun. From the use of the 9/64-inch round-hole top screen on the Clipper, it was found that 69.2 percent was in the 9/64 to 10/64-inch size. The 1,000 pounds of 7/64 to 10/64-inch Clipper-sized seed, rerun over the Eureka, produced 288 pounds, or 28.8 percent, above 10/64-inch in size.

In order to determine the cause of the difference in seed size from the two cleaners, size of perforation in both 7/64 and 10/64-inch round-hole screens on both cleaners was inspected. Hundreds of perforations were checked and found to be accurate at 7/64 inch and at 10/64 inch. The pitch on the Clipper cleaner screens was then checked at all four extreme sets, to determine what differences might be obtained in percentage recovery, number of seedballs per pound, and in germination characteristics. The results of the screen-pitch tests are given in table 3.

**Table 3.**—Comparison of screen pitch on 68D Clipper on the characteristics of segmented seed.

| Pitch of screens | Weight per bushel, pounds | % recovery* | Segmented seed data: Number seedballs per pound | Sprout count per 100 seeds tested: % germ. | Singles | Multi-ples | Total |
|---|---|---|---|---|---|---|---|
| 1. Both 7/64" & 10/64" screens at maximum pitch (steep slope) | 30 | 66.25 | 35,000 | 91.7 | 22.0 | 69.3 | 171.3 |
| 2. Both 7/64" & 10/64" screens at minimum pitch (flat slope) | 30 | 67.27 | 35,558 | 91.5 | 25.0 | 66.5 | 177.0 |
| 3. No. 10/64" maximum pitch No. 7/64" minimum pitch | 31 | 66.36 | 34,503 | 91.7 | 23.7 | 68.0 | 174.0 |
| 4. No. 10/64" minimum pitch No. 7/64" maximum pitch | 31 | 68.07 | 35,576 | 87.7 | 21.7 | 66.0 | 166.0 |

*880 pounds whole seed used for each test run.

From these data it appears that there was very little difference in percentage recovery or number of seedballs per pound in any of the four screen sets, and the lower percentage germination obtained from No. 4 is probably not a reliable difference.

## Drill Tests

Since there was some question as to how Clipper-sized seed would work in new precision-type beet drills having planting plate cells of 11/64 inch in diameter, samples of mill lots 3 and 46 (table 1) were sent to the Beet Sugar Development Foundation for a planting test in the John Deere No. 66 Drill. The seed plate used in the planter test was pressed steel .125 ± .001 inch thick, with 72 cells punched 11/64 inch in diameter.[3] The plate speed in the test was 55 feet per minute (3.25 MPH) or 7.80 cells per foot of ground travel.

Planter performance is summarized in table 4, along with seed characteristics.

**Table 4.** Percentage of cell fill, seed damage, along with poundage planted per acre (in 20-inch rows) of viable seeds for lots No. 3 and No. 46.

| Characteristic | Mill lot: No. 3 | No. 46 |
|---|---|---|
| Number seedballs per pound | 43,324 | 34,105 |
| Percent germination | 84.5 | 95.5 |
| Percent cell fill | 97.5 | 88.8 |
| Percent planter damage | 2.69 | 2.06 |
| Pounds planted per acre (20-inch rows) | 4.588 | 5.308 |
| Viable seeds per acre (20-inch rows) | 168,054 | 172,768 |

## Discussion

It is apparent that larger processed seed was produced by the 68D Clipper than was obtained from the No. 7 Eureka, when both mills were equipped with 7/64-inch and 10/64-inch round-hole screens. The result was not explained by the pitch of the screens on the Clipper.

There are certain differences in these two mills which are likely to account for the differences in seed size. The shake of the Clipper screens is slower than that of the Eureka. The most important difference, however, between these two mills appears to be in action of the screen deck (or shoe). The Eureka is equipped with a Buhler eccentric-less drive, and the 68D Clipper with an eccentric drive. The Buhler drive imparts a vibrating action to the shoe, and eliminates the abrupt jerking motion common to cleaners not so equipped. Because of this difference in drive, beet seed tends to slide down the screens of the Eureka, whereas on the Clipper the seed tends to tumble. Segmented seed is extremely variable in shape, and on this type of material many unround seeds will go through round-hole screens because of the jerking action of the 68D Clipper shoe. With the Eureka, seeds do not drag on the screens, and unusual shapes are commonly recovered in oversize fractions.

[3]Cells in 1947 planter plates of this make of drill are punched .168 inch in diameter.

## Conclusions

The results of these tests indicate that different makes of seed cleaners may grade, or size, segmented beet seed very differently. Therefore, seed sized 7/64 to 10/64 inch may or may not fill all cells of 11/64-inch size in drill planter plates. In order that the best planting be obtained, greater efforts must be made to produce processed seed which will be suitable for each make of drill.

## Summary

Segmented beet seed sized over the 68D Clipper seed cleaner equipped with 7/64-and 10/64-inch round-hole screens, was found to be larger in size than segmented seed sized over a No. 7 Eureka seed cleaner equipped with screens having the same size round-hole perforations.

Changes in pitch of screens in the 68D Clipper shoe made slight but very insignificant changes in segmented-seed characteristics.

It was observed that the shake of the No. 7 Eureka shoe was faster than that of the 68D Clipper; and that the Eureka was equipped with an eccentric-less drive, while the Clipper had an eccentric drive. Both of these differences could affect the size of segmented seed.

Seed sized 7/64 to 10/64 inch obtained from each seed cleaning mill was tested in a John Deere No. 66 precision drill equipped with 11/64-inch planter plate cells. A 97.5-percent cell fill was obtained from Eureka-sized seed, and an 88.8-percent cell fill from Clipper-sized seed.

# Plant Improvement and Seed Production

# Progress in Breeding Sugar Beets for Resistance to Aphanomyces Root Rot

C. W. Doxtator and A. R. Downie[1]

Breeding sugar beets for resistance to *Aphanomyces cochlioides* (drechs) has been carried on since 1942 in the southern Minnesota-northern Iowa beet-growing area by the American Crystal Sugar Company (1).[2] In the first years of this work very little progress was made, but in 1945 marked differences in resistance were observed between several open-pollinated plant progenies of the American No. 1 variety. In southern Minnesota that year, a ½-acre area of sugar beets severely infested with the disease produced 417 roots, many of which were very small and misshapen. From these roots, 71 open-pollinated plant progenies were obtained and tested in 1946 under medium-severe disease conditions at the South East Experiment Station, Waseca, Minnesota, and in four other locations where the disease was less severe or absent. The 71 progenies showed varying degrees of resistance in the Waseca, Minnesota, test; and 20 of the most resistant progenies of the 71 were selected for seed production and field test in 1947.

The results obtained from the roots of these 20 (1946) progenies in the 1947 tests are given in this report, together with data on the 1947 selections made from these resistant lines.

## Experimental Procedure

There were 249 beets selected from the best 20 lines (or progenies) of the 71 in test in southern Minnesota in 1946, and these were shipped to Rocky Ford, Colorado, in December 1946, to be replanted in the Company's greenhouses for winter seed production. All beets from the 20 lines were replanted, there being no discard of beets for other characters prior to replanting. At flowering time, each plant was self-pollinated, using one No. 8 Kraft bag, and in addition, one No. 8 Kraft bag was placed on each plant for sib-pollination of plants *within* the line progenies by "bag switching" technique. All open-pollinated seed was harvested by individual plant as in previous years.

All seedlots were harvested in late April, and in time for test plantings in the 1947 summer season. Of the 249 roots planted in the greenhouses, 72 produced adequate quantities of open-pollinated seed to plant at least 240 feet of beet row at a planting rate of 7 seeds per foot, and an additional 123 produced seed adequate to plant at least 80 feet of row at this planting rate. One hundred plants produced inbred seed in amounts suf-

[1]Plant Breeder and Plant Pathologist, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

[2]The numbers in parentheses refer to literature cited.

ficient to plant 1 to 25 hills; and 38 sibbed progenies were obtained in amounts adequate to plant 15 to 75 hills.

After all seedlots were made up, surplus seed of the 195 open-pollinated progenies was bulked into two lots, 6-404a and 6-404b, the former being a bulk lot judged to be the best of the selections. This lot was planted in a strip test in comparison with the three check varieties, U. S. 216, 1-9-00[3], and American No. 3, on the test field at Mason City, Iowa.

## Plan of 1947 Tests

All the 100 inbred seedlots and the 38 sibbed seedlots were planted in late May at Rocky Ford, Colorado, in nursery plots. The 195 open-pollinated plant progenies were planted in southern Minnesota and northern Iowa in 6 test fields. The locations of the test fields and the root rot infestation which developed in these fields were as follows:

Field A—extremely heavy infestation, South East Experiment Station, Waseca, Minnesota

Field B—moderate infestation, J. Johnson Farm, Mankato, Minnesota

Field C—traces of disease, August Seys Farm, Mankato, Minnesota

Field D—traces of disease, S. Poncin Farm, St. Peter, Minnesota

Field E—no infestation, P. Ritz Farm, St. Peter, Minnesota

Field F—heavy infestation, G. Sprole Farm, Mason City, Iowa

In each test field the seed progenies were planted in 2 replications of plots 20 feet long by 1 row wide. The varieties, U. S. 216, 1-9-00, and American No. 3, which were used as checks, were planted in adjacent single-row strips through the field, there being at least 11 or 12 rows of resistant progenies between each 3-row strip of checks. Alleys 3 feet wide crossed the test fields at 20-foot lengths, i. e.—at the end of the plots. Tests A and F included all 195 seed progenies, and in tests B, C, D, and E, the 72 high seed-producing lines of the 195 were planted. All 20-foot row plantings were made with 140 seedballs, or 7 seedballs per foot of row. No seed treatment was used on seed in any of the plantings.

Laboratory germination tests were run on each of the seedlots produced by the 195 lines. Sixteen of the lines were lower than 70 percent in germination, but were considered to be high enough to produce adequate stands at the planting rate planned. The other 179 line seedlots ranged up to 100 percent germination. All lines produced sufficient stand, in all tests, for a thinned stand of one beet per foot of field row.

## Experimental Results

**Plot Tests.**—The data obtained from the Waseca Experiment Station in 1946 on the 71 lines tested that year, indicated substantial improvement over all check varieties, not only from notes on vigor of foliage and percentage stand, but also on actual weight of beets harvested per plot. A check on this 1946 result was obtained from the strip test plantings of 6-404a (which,

[3]1-9-00 is a USDA selection known to be extremely susceptible to *Aphanomyces* root rot.

as described above, was a seed increase from part of the 1946 selected roots) and the three check varieties, U. S. 216, 1-9-00 and American No. 3. The complete results of this test are given in table 1.

**Table 1.—Yield of 6-404a in comparison with the commercial varieties No. US 216, American No. 3, and the Susceptible Check 1-9-00, Mason City, Iowa, 1947.**

| Block No. | Yield in Tons per Acre | | | |
|---|---|---|---|---|
| | US 216 | 1-9-00 | American No. 3 | 6-404a |
| 1 | 1.634 | 0.000 | .653 | 3.928 |
| 2 | 1.143 | 0.000 | .326 | 7.024 |
| 3 | 1.143 | .653 | 1.960 | 8.984 |
| 4 | 2.614 | 1.470 | 2.450 | 8.167 |
| 5 | 0.000 | 0.000 | 1.306 | 9.905 |
| 6 | 3.594 | .490 | 3.267 | 9.964 |
| Average | 1.69 | .44 | 1.66 | 8.00 |
| Average of three check varieties | | 1.60 | | |
| Total number of marketable beets per acre at harvest | 5,009 | 1,307 | 4,574 | 15,464 |

In this test, a strip of 5 rows wide and 120 feet long was harvested in six 20-foot blocks; 6-404a was a 2-row strip, and the three adjacent check varieties were single-row strips. All beets less than .33 pound were considered non-marketable.

**Selection Results.**—The severity of the disease in the test areas in 1947 did not follow quite the same pattern as in 1946. Fields C, D, and E, were found to be practically free of the disease, and therefore could not be used for critical selection purposes. Field B, in which moderate infestation occurred in 1946, had a similar amount of infestation in 1947, but this test area, due to cultural difficulties, was so uneven in stand that it was considered advisable not to select in this field. At Mason City (field F), the disease developed in similar fashion to that of the Waseca test in 1946, having a severe amount of damping off after emergence, and with continuing damage to remaining plants until early August when a drought occurred which reduced damage. At Waseca, an area adjacent to the one used for the 1946 replicated progeny test was selected in 1947. This area proved to be much more severely infested with the *Aphanomyces* rot than the 1946 test area. Selection for increased resistance in 1947 was, therefore, confined to the Mason City, Iowa, and the Waseca, Minnesota, areas (fields A and F).

In early August, vigor of foliage notes, as well as stand counts, were taken on all plots of progeny lines and check varieties at each of the two locations. The Waseca test was found to be so severely damaged that differences in resistance between the plant lines was very small. At Mason City, however, differences in both vigor of growth and surviving stand were observable between lines, and generally good agreement between replications of these lines for stand and vigor was obtained. Further, 13 progenies which were best at Waseca were likewise in the highest category for foliage vigor and percentage stand at Mason City.

Since the Mason City, Iowa, test, considered as medium severe, showed the greatest differences in resistance between lines, plans were made to make the largest selection of plant lines in this test; and in the Waseca test

field, it was planned to select beets from all lines which showed some resistance to the disease.

Selection of 53 lines was made from the Mason City test in late September, after a recheck of vigor and stand notes had been made. In table 2 are given vigor indices and stand counts obtained on these selections, compared with check varieties.

**Table 2.—Average percentage stand and vigor indices for 53 selected plant lines compared with the average of all lines tested, and with susceptible checks, Mason City, Iowa, 1947.**

| Varieties | Vigor of Foliage Indices* | | Percent Stand | |
|---|---|---|---|---|
| | Average | Range | Average | Range |
| 195 lines in test | 2.96 | 1.0-5.0 | 56.75 | 22.5-87.5 |
| 53 lines selected | 2.45 | 1.0-3.0 | 69.34 | 55.0-87.5 |
| Check varieties: | | | | |
| U.S. 216 | 4.12 | | 52.00 | |
| 1-9-00 | 4.74 | | 25.48 | |
| American 3 | 4.29 | | 38.40 | |

*Vigor Index: 1 = vigorous, 5 = weak.

From the 53 lines selected in this field, a total of 557 beets were obtained, all of which weighed more than 0.7 pound per beet.

The striking difference in stand and vigor of foliage between resistant lines and checks in the Mason City test is shown in figure 1. The susceptibility of the check varieties to root rot is observable in both the first and second rows of 20-foot plots, as compared to the several resistant lines growing in adjacent rows.

Figure 1.—(Foreground) left to right: American No. 3, 1-9-00, U.S. 216, A-122, A-132, A-102.

Figure 2 shows selected roots of resistant line A-93, compared with the roots of the American No. 3 check. A-93 produced 30 beets from 40 feet of row (2 plots), 13 of which were selected. The check variety produced 12 beets from 40 feet of row, 11 of which are shown.

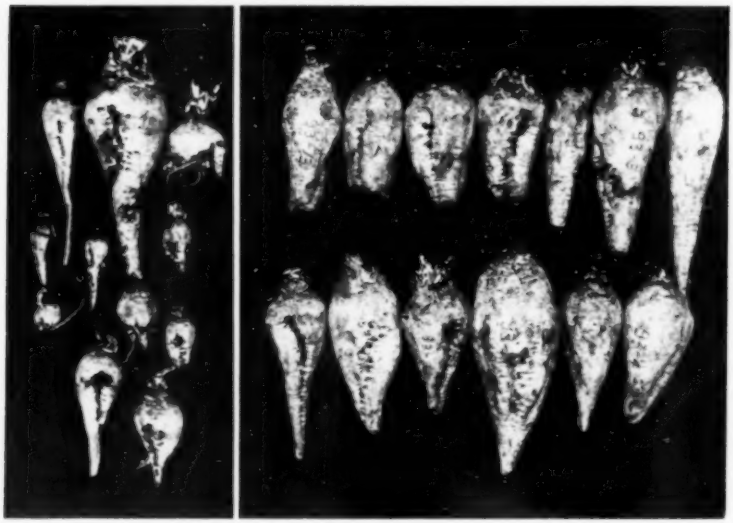

Figure 2.—Left, American No. 3 check; right, line A-93.

In December 1947, a further separation of the roots of the 53 lines was made for size and shape, into (a), (b), and (c) selections. This procedure was considered desirable, since not all roots selected can be accommodated in the greenhouses; and further, since the less desirable plants of this final selection were far superior in resistance to the check varieties in the test field, these are usable for commercial bulk-seed increase as a semi-resistant variety. The (c) selection was of beets weighing more than .70 pound and less than 1.40 pounds. Beets of the (a) and (b) selections weighed more than 1.40 pounds per beet; and the (a) selection was of lines having the largest number of beets weighing more than 1.40 pounds. Data on these final selections is given in table 3.

The replicated test plantings at Waseca, Minnesota, and the nursery plantings of self and sib progenies at Rocky Ford, Colorado, were also used for selection purposes. Of the 195 progeny lines in the Waseca test, 46 were considered resistant enough to be selected, and 205 beets were obtained. At Rocky Ford, beets from 24 inbred lines and 33 sib progenies were selected. These self and sib progenies will be further inbred in the 1947-48 winter season.

Table 3.—Number of beets selected and average weight of final 1947 root rot resistant selections, Rocky Ford, Colorado, 1947.

| Selection | 1947 plant line | Number of beets selected | Average weight per beet, pounds |
|---|---|---|---|
| A | A-32 | 8 | 2.05 |
| | A-66 | 10 | 1.88 |
| | A-71 | 9 | 2.10 |
| | A-78 | 8 | 1.75 |
| | A-86 | 11 | 1.86 |
| | A-93* | 11 | 1.96 |
| | A-106 | 8 | 1.73 |
| | A-145 | 11 | 1.76 |
| | A-150 | 9 | 1.91 |
| | A-165 | 8 | 1.75 |
| | A-184 | 8 | 1.73 |
| | A-189 | 10 | 1.95 |
| Total and average | | 111 | 1.87 |
| B | ----- | 170 | 1.87 |
| C | ----- | 276 | 1.03 |

*See figure 2.

## Conclusions

The 195 individual plant lines, obtained from 20 lines resistant to *Aphanomyces cochlioides* in 1946 at Waseca, Minnesota, showed similar resistance to the parent lines in a similar epidemic at Mason City, Iowa, in 1947. Under the very severe disease conditions existing at Waseca, Minnesota, in 1947, 13 of these 195 progenies were much superior to the check varieties in resistance. These same 13 lines were superior to others in the lesser disease conditions prevalent in the Mason City test. It is concluded, therefore, that substantial resistance to this root disease has been obtained. This conclusion is further substantiated by a yield test of a seed-lot representing the best of the 20 lines selected in 1946, compared with the 3 check varieties. This selection, 6-404a, produced a yield of beets five times that of the average of the three check varieties.

The 1947 test near Mason City, Iowa, showed great differences as an average, between selected lines and check varieties, but much lesser differences between lines. In the 1946 tests, the parent lines showed great differences *between lines,* as well as between all selected lines and checks. It is concluded, therefore, that future improvement in resistance in the plant material now on hand will not be as great from mass selection, or from open-pollinated mother-line selection, as from lines developed by closer breeding methods.

## Summary

Seed obtained from the selection made for resistance to *Aphanomyces cochlioides* in 1946, was compared with three susceptible varieties in plot tests in a medium severely infested field in 1947. The three susceptible varieties yielded an average of 1.60 tons per acre, and the resistant selection 8.00 tons per acre.

Fifty-three open-pollinated plant lines were found to be superior in resistance out of 195 tested in 1947, in a field having a medium-severe

infestation of *Aphanomyces cochlioides*. Forty-six plant lines showed good resistance in a severely infested field. Of the 46, the 13 best lines were found to be highly resistant in the medium severely infested field.

Selections were also made in 24 inbred lines and 33 sib progenies from nursery plots, for further self-pollination and test for resistance to disease.

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1946. Breeding for resistance to *Aphanomyces* root rot. Proc. Amer. Soc. Sug. Beet Tech. (Regional) Page 134-138 mimeo.

# Progress Report on Breeding of Sugar Beets in Minnesota for Resistance to Black Root[1]

H. W. Bockstahler and Oscar E. Reece[2]

In recent years the disease of sugar beets, commonly called black root, has received increased attention from numerous investigators. *Aphanomyces cochlioides* drechs. has been found most frequently in the humid area of the United States, although many fungi may be involved in this disease complex. This fungus parasite is capable of killing both seedlings and older sugar beet plants. A review of the black-root disease problem and possibilities for its control was presented at the fourth general meeting of this Society in 1946 (1).[3]

Observations that varieties of sugar beets differ in their resistance to rotting by *A. cochlioides* led to the development of a program of breeding for resistance to this organism by the Division of Sugar Plant Investigations, United States Department of Agriculture, and Minnesota Agricultural Experiment Station. A preliminary report on this project was presented by Henderson and Bockstahler (3) in 1946. A similar project was undertaken by the American Crystal Sugar Company as reported in 1947 by Doxtator and Downie (2). Active cooperation between these agencies was begun in 1946 and continued in 1947 for the field testing of resistant selections. This paper is a progress report presenting the results of field tests in 1947 of selections developed by the Division.

## Materials and Methods

**Seed Sources.**—The seedlots tested in 1947 were individual plant progenies derived from open-pollinated mother beets in the greenhouse and in the field. The seed obtained in the greenhouse was produced by the polycross method whereas that from the field was produced in a group planting of beets from several different varieties or group plantings of beets from single varieties.

For the polycross method of seed production roots having acceptable size and shape were selected in a field heavily infested with *A. cochlioides* in the fall of 1945 and placed in cold storage until December 1. The best 15 roots from 50 lines were then planted in 8-inch pots and placed in the greenhouse arranged in 15 blocks of 50 roots each.

[1]Cooperative investigations of the Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U.S. Department of Agriculture, and Minnesota Agricultural Experiment Station, Paper No. 2396, Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2]Assistant Pathologist, and Assistant Agronomist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering. The writers wish to thank Dr. G. H. Coons, Principal Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S. Department of Agriculture, under whose direction these investigations were made, and Dr. H. K. Hayes, Chief, Division of Agronomy and Plant Genetics, and Dr. E. C. Stakman, Chief, Division of Plant Pathology and Agricultural Botany, Minnesota Agricultural Experiment Station, for helpful suggestions and criticisms during the course of these investigations and in the preparation of the manuscript.

[3]The numbers in parentheses refer to literature cited.

Each block contained 1 root from each of the 50 lines randomized within the blocks to permit equal opportunity for cross-fertilization to occur between the different lines. At intervals during the period of flowering a hand electric blower was directed toward the plants to aid in the dispersal of pollen. Of the 750 roots planted, 569 came into flower and were harvested individually.

The surplus roots not used in the greenhouse were retained in storage until May, 1946. All sound roots were then planted in the field at Waseca, Minnesota, in three isolated groups spaced approximately ¼-mile apart: 1.—mother beets from selections of U. S. 216; 2.—selections from Minnesota Synthetic No. 1 and 3.—all remaining beets from various sources including extra roots from some of the lines used in the polycross. By planting these mother beets at Waseca where the soil was heavily infested with A. *cochlioides* it was hoped that additional elimination by disease might occur. At harvest, seed was saved from only those plants whose roots were still solid and showed no signs of rot.

## Field Plot Methods

The tests were made in heavily infested soil at the Southeastern Experiment Station, Waseca, Minnesota. In cooperation with the American Crystal Sugar Company, four additional tracts were located in Southern Minnesota, however, in two of these, disease incidence was moderate and no disease was evident in the others so that only the plots at Waseca were harvested.

Rows, 20 inches apart, were marked with a 4-row beet drill and fertilizer (4-24-12) applied in the row at the rate of 100 pounds per acre. All seed was treated with Arasan and planted with a V-belt hand planter of the type commonly used for planting small grains at the Minnesota Agricultural Experiment Station. Plots were single rows 10 or 20 feet long, depending on the quantity of seed available. All seedlots were planted in duplicate, randomized plots with the exception of a few in which only sufficient seed was available for a single 10-foot row. As check varieties, U. S. 216, moderately resistant; S.P. 1-9-00, very susceptible, and American No. 3, moderately resistant commercial variety, were planted at 12-row intervals throughout the field.

Stand counts after thinning and relative vigor of top growth in comparison with U. S. 216 were recorded. These data were used to determine the progenies considered worth lifting at harvest. In order to verify these conclusions, 310 twenty-foot rows were lifted and the roots sorted into healthy and diseased classes. Size and shape of roots were used as the basis for the separation. When compared with the roots of U. S. 216 from the nearest plot of that variety, the above conclusions were justified and harvest of the remaining progeny rows was determined on that basis.

The performance of each progeny row was compared with that of the nearest row of U. S. 216 and classified into six categories as follows:

Class +3, three times as many healthy roots as U. S. 216; +2, two times; +1, one and one-half times; 0, equal; —1, less; and —2, not harvested but inferior to U. S. 216 in stand and top growth vigor. This paper presents the results of the field tests of 506 open-pollinated seed progenies from mother beets planted in the greenhouse and 127 open-pollinated seed progenies from mother beets planted in the field.

## Experimental Results

The development of sugar beet varieties resistant to *A. cochlioides* consists essentially in exposing mixed populations to the soil inhabiting pathogen. Genetic changes in both the host and the pathogen may operate to complicate the problem. Through successive exposures susceptible plants may be screened out leaving the resistant individuals. When seasons unfavorable to the fullest development of reaction between host and pathogen are encountered, the screening process is incomplete and must be continued in succeeding years. The tests in 1947 were the second severe exposure of the selections to disease in the field.

The results of the performance of 506 progenies from seed produced in the greenhouse by the polycross method in comparison with the check variety, U. S. 216 are given in table 1. One hundred and seventy-five progenies (34.6 percent) produced from 1½ to 3 times as many healthy roots as U. S. 216. Two hundred and forty-five progenies (48.4 percent) were equal or superior to the check.

**Table 1.**—Frequency distribution of mean yield of healthy roots, in heavily infested soil, of progenies of open-pollinated seed produced in the greenhouse by the polycross method in comparison with U.S. 216. (Classified according to numbers of healthy roots produced.)

| Source of selection | Classes[1] | | | | | | Total progenies tested | As percentages of U.S. 216 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | +3 | +2 | +1 | 0 | —1 | —2 | | Superior | Equal | Inferior |
| | | | | | | | | (percent) | (percent) | (percent) |
| 0-2-07 | | | | | 2 | 7 | 9 | | | 100.0 |
| 0-2-022 | | | 1 | | 1 | 7 | 9 | 11.1 | | 88.9 |
| 0-4-01 | 1 | | | 2 | | 1 | 4 | 25.0 | 50.0 | 25.0 |
| 0-6-07 | | | | | 2 | 5 | 7 | | | 100.0 |
| 1-8-00 | 1 | 5 | 6 | 7 | 4 | 15 | 38 | 31.6 | 18.4 | 50.0 |
| 1-12-00 | 1 | | | 3 | | 4 | 8 | 12.5 | 37.5 | 50.0 |
| 2-1-00 | | | 2 | 1 | 1 | 6 | 10 | 20.0 | 10.0 | 70.0 |
| 3-6-00 | 4 | | 4 | 2 | 1 | 4 | 15 | 53.4 | 13.3 | 33.3 |
| 3-9-0 | | 1 | 1 | 1 | | 4 | 7 | 28.6 | 14.3 | 57.1 |
| 3-10-0 | 1 | 2 | 2 | | | 4 | 9 | 55.6 | | 44.4 |
| 4-7-00 | | | | | | 8 | 8 | | | 100.0 |
| 4-1901-01 | | 1 | 3 | | | 4 | 8 | 50.0 | | 50.0 |
| W[2] | 5 | 3 | 9 | 3 | 2 | 10 | 32 | 53.1 | 9.4 | 37.5 |
| S[2] | 10 | 23 | 38 | 29 | 17 | 67 | 184 | 38.6 | 15.8 | 45.6 |
| W & S[2] | 4 | 4 | 6 | 8 | 2 | 14 | 38 | 36.8 | 21.1 | 42.1 |
| Am. No. 1 | | 4 | 7 | 3 | 5 | 17 | 36 | 30.6 | 8.3 | 61.1 |
| Am. No. 3 | | 4 | | | 1 | 5 | 10 | 40.0 | | 60.0 |
| U.S. 216 | | 1 | 2 | 1 | 1 | 7 | 12 | 25.0 | 8.3 | 66.7 |
| Minn. Syn. No. 1 | 2 | 4 | 7 | 8 | 1 | 29 | 51 | 25.5 | 15.7 | 58.8 |
| Miscellaneous[3] | 1 | | 5 | 2 | 3 | | 11 | 54.5 | 18.2 | 27.3 |
| Totals and averages | 30 | 52 | 93 | 70 | 43 | 218 | 506 | 34.6 | 13.8 | 51.6 |

[1]Classes: +3, produced 3 times as many healthy roots as U.S. 216; +2, 2 times; +1, 1½ times; 0, equal; —1, less; —2, inferior to U.S. 216 in stand and top growth vigor so were not harvested.

[2]W, S, and W & S—selections obtained from genetic study by Dr. J. O. Culbertson. Roots above average in weight, sucrose, or both.

[3]Miscellaneous—original source not recorded.

As shown in table 2, 22 (17.3 percent) of the 127 progenies from the mother beets producing open-pollinated seed in the field yielded 1½ to 3 times as many healthy roots as U. S. 216. Thirty five (27.5 percent) were equal or superior to the check. It should be mentioned that the roots which produced these seedlots were mostly residual mother beets remaining in storage after the best ones were selected for planting in the greenhouse. This may account for the poorer results from this group of progenies as contrasted with those shown in table 1. The performance of seedlots from the two plantings is compared in table 3. In each of the three sugar beet strains listed, a greater percentage of the progenies from the greenhouse or polycross planting equalled or exceeded the check than the progenies from the field plantings.

**Table 2.**—Frequency distribution of mean performance in heavily infested soil of progenies of open-pollinated seed produced in the field in comparison with U.S. 216. (Classified according to numbers of healthy roots produced.)

| Source of selection | Classes[1] | | | | | | Total progenies tested | As percentages of U.S. 216 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | +3 | +2 | +1 | 0 | —1 | —2 | | Superior | Equal | Inferior |
| | | | | | | | | (percent) | (percent) | (percent) |
| 0-1-022 | | | | | | 1 | 1 | | | 100.0 |
| 0-2-07 | | | 2 | | | | 2 | 100.0 | | |
| 0-2-026 | | | | | | 1 | 1 | | | 100.0 |
| 0-4-01 | | | | | 1 | 1 | 2 | | | 100.0 |
| 0-10-0 | | | | | | 1 | 1 | | | 100.0 |
| 1-7-00 | | 1 | | | | 1 | 2 | 50.0 | | 50.0 |
| 1-8-00 | | 1 | 3 | 1 | 3 | 1 | 9 | 44.4 | 11.2 | 44.4 |
| 1-10-0 | | | 1 | | | | 1 | 100.0 | | |
| 1-19-0 | | | | | | 1 | 1 | | | 100.0 |
| 2-1-00 | 2 | | | 1 | | 11 | 14 | 14.3 | 7.1 | 78.6 |
| 3-9-0 | | | | | | 3 | 3 | | | 100.0 |
| 3-10-0 | | | | | | 2 | 2 | | | 100.0 |
| 3-1311-0 | | | | | | 2 | 2 | | | 100.0 |
| 4-14-0 | | | 1 | 2 | | | 3 | 33.3 | 66.7 | |
| 4-1901-01 | | | 3 | 2 | 1 | 8 | 14 | 21.4 | 14.3 | 64.3 |
| 8-266-0 | | | | | | 1 | 1 | | | 100.0 |
| Lot 1233 | | 1 | | | | 1 | 2 | 50.0 | | 50.0 |
| Am. No. 1 | | | | | | 2 | 2 | | | 100.0 |
| Am. No. 3 | | | | | | 1 | 1 | | | 100.0 |
| U.S. 216 | | | | 1 | 1 | 14 | 16 | | 6.3 | 93.7 |
| Minn. Syn. No. 1 | 2 | | 3 | 4 | 1 | 23 | 33 | 15.2 | 12.1 | 72.7 |
| Misc.[2] | 1 | | 1 | 2 | 1 | 9 | 14 | 14.3 | 14.3 | 71.4 |
| Totals and averages | 5 | 3 | 14 | 13 | 8 | 84 | 127 | 17.3 | 10.2 | 72.5 |

[1]Classes: +3, produced 3 times as many healthy roots as U.S. 216; +2, 2 times; +1, 1½ times; 0, equal; —1, less; —2, inferior to U.S. 216 in stand and top growth vigor so were not harvested.

[2]Miscellaneous—original source not recorded.

**Table 3.**—Comparison of sugar beet progenies from seed produced in the greenhouse by the polycross method and seed produced in the field with yield of healthy roots when compared with the check variety, U.S. 216.

| Source of selection | Mother beet location | Number of progenies tested | As percentages of U.S. 216 | | |
|---|---|---|---|---|---|
| | | | Superior | Equal | Inferior |
| | | | (percent) | (percent) | (percent) |
| | Greenhouse | 10 | 20.0 | 10.0 | 70.0 |
| 2-1-00 | Field | 14 | 14.3 | 7.1 | 78.6 |
| Minn. | Greenhouse | 51 | 25.5 | 15.7 | 58.8 |
| Syn. No. 1 | Field | 33 | 15.2 | 12.1 | 72.7 |
| | Greenhouse | 12 | 25.0 | 8.3 | 66.7 |
| U. S. 216 | Field | 16 | 0.0 | 6.3 | 93.7 |

Mother beets have been selected and placed in storage from many of the progenies classified as superior in the tests in 1947. Further testing and selection is necessary but progress is being made in the development of strains resistant to black-root disease.

## Summary

Black root of sugar beets is caused by a number of soil inhabiting, pathogenic fungi, principally *Aphanomyces cochlioides*, in the humid area of the United States.

Observations that varieties of sugar beets differed in their resistance and susceptibility to this organism led to the development of a program of breeding for resistance.

Seed from individual mother beets was produced in the greenhouse by the polycross method and in the field. When planted in the field in soil heavily infested with *A. cochlioides*, 34.6 percent of the progenies produced in the greenhouse yielded 1½ to 3 times as many healthy roots as the check variety, U. S. 216. Seventeen percent of the progenies from mother beets planted in the field exceeded U.S. 216 in numbers of healthy roots.

The polycross progenies from the superior material presents concrete evidence of the value of intensive selection showing that inheritance of resistance and the combination of resistant lines is a method of obtaining even higher resistance.

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# Comparative Reaction of Sugar Beet Strains to Black Root in Field Tests at Blissfield, Michigan, and Waseca, Minnesota, in 1947[1]

JOHN O. GASKILL, H. W. BOCKSTAHLER, AND OSCAR E. REECE[2]

THE WORK of various investigators relative to the nature, causes, and control of the black-root disease of sugar beets was summarized by Coons, Kotila, and Bockstahler (3)[3] in 1946. They emphasized the role of *Aphanomyces cochlioides* (drechs.) as the chief causal organism, called attention to the moderate degree of black-root resistance observed in U.S. 216, a leafspot-resistant strain, and discussed possibilities of control of black root through breeding. Henderson and Bockstahler, (5) in 1946, reported the results of 1945 field trials at Waseca, Minnesota, in which the progenies of certain roots selected under severe black-root exposure showed considerable promise, being distinctly more resistant than U.S. 216 which was used as a check variety. More recently, reports on progress made in black-root-resistance breeding were given by Doxtator and Downie (4) and by Coons (2).

Since a strain or variety of crop plant resistant to a given species of fungus in a particular locality may not necessarily be resistant to that species in other localities, due to differences in biotypes of the pathogen involved or for other reasons, an experiment was conducted in 1947 for the purpose of comparing the reaction of sugar beet strains to black root under field conditions at Blissfield, Michigan, and Waseca, Minnesota.

## Material and Methods

Seed of 19 strains of sugar beets, chiefly inbred lines, was obtained from the leafspot-resistance breeding project of the U. S. Department of Agriculture. It was assumed that several of these strains, because of their derivation from U.S. 216, probably would be more or less resistant to black root. Certain ones were considered susceptible, and the resistance of the remainder was unknown. Forty-three seedlots arising from black-

[1]Contribution from the Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U.S. Department of Agriculture, in cooperation with the Department of Farm Crops, Michigan Agricultural Experiment Station, and with the Division of Plant Pathology and Agricultural Botany and the Division of Agronomy and Plant Genetics, Minnesota Agricultural Experiment Station. Assistance with certain phases of the program, rendered by the following organizations, is gratefully acknowledged: American Crystal Sugar Company, Farmers and Manufacturers Beet Sugar Association, and Great Lakes Sugar Company. Paper No. 2395, Scientific Journal Series, Minnesota Agricultural Experiment Station.

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[3]The numbers in parentheses refer to literature cited.

root-resistance breeding work of the Department at Waseca, Minnesota, were included in the study. Each of the latter seedlots had been harvested from an individual open-pollinated sugar beet plant in an outdoor seedplot planted entirely with mother beets having a history of one or more generations of selection under severe black-root exposure. These 43 seedlots or "strains" are included, among others, in a separate paper by Bockstahler and Reece (1).

Fields used for the 1947 tests were known to have a history of severe black-root damage. As a safeguard against extreme losses at Blissfield, phosphate fertilizer (0-20-0) was applied broadcast at the rate of approximately 250 pounds per acre to a part of the land, two replications of the 62 strains occurring in that area and two replications occurring on unfertilized land. Two replications only were planted at Waseca, entirely on land receiving 4-24-12 fertilizer in the row at the rate of 100 pounds per acre. All fertilizer was applied before seeding. Single-row plots 20 feet long were used at both locations, with rows 20 to 22 inches apart. Randomized-block experimental design was employed for the test strains, with systematically spaced rows of resistant and susceptible checks—U.S. 216 and 1-9-00, respectively—for purposes of comparison. All seed was treated with Arasan to inhibit the attack of *Pythium* spp. and other damping-off pathogens. Planting was performed by means of hand drills, with rate of seeding in each plot adjusted in conformity with germination. The seeding rate was relatively heavy, approximating one potential seedling per inch of row. Seedbed preparation was delayed considerably at both locations, and as a consequence planting was postponed until May 26 at Waseca and June 24-25 at Blissfield.

Precipitation received at Waseca soon after planting was abundant, and seedling emergence was satisfactory. Black-root attack was severe from the time of emergence until the plants reached thinning age, and thinning was postponed somewhat on that account. During the remainder of the season precipitation was moderate and marked recovery was shown throughout the experiment, especially among the plants of resistant strains. At Blissfield, the seedbed was dry at planting time, and germination occurred as a result of a heavy artificial sprinkling of the field on July 10. Initial seedling stands were excellent and black-root losses were relatively slight during the first 2 weeks after emergence. With periodic sprinkling, supplementing natural rainfall, the disease in the non-phosphated area caused moderate to relatively severe seedling losses about thinning time and, as at Waseca, thinning was postponed somewhat on that account. Marked stunting of the more susceptible strains was evident during the remainder of the season. Black-root attack in the phosphated area was much less severe, and consequently the two replications in that part of the field were abandoned before harvest. Because of disease conditions at thinning time, and in order to provide a relatively large number of plants for selection purposes, 6- to 8-inch spacing was attempted insofar as possible.

Table 1.—Comparison of 19 leafspot-resistant sugar beet strains under black-root conditions in field tests at Blissfield, Michigan, and Waseca, Minnesota, 1947; results given as 2-plot averages for each location.

| Strain | | Foliage vigor reading[a] | | | Estimated quantity of foliage per plot[b] | | | Harvest results (per plot) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Healthy roots | | | Total roots | | | Total weight of roots | | |
| Temp. No. | S.P.I. No. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. |
| | | | | | | | | No. | No. | No. | No. | No. | No. | lb. | lb. | lb. |
| 1 | 0-13-0 | 5.0 | 4.5 | 4.8 | 97.5 | 13.5 | 55.5 | 4.5 | 2.0 | 3.3 | 19.0 | 3.0 | 11.0 | 2.85 | 1.40 | 2.13 |
| 2 | 0-259-0 | 4.5 | 4.3 | 4.4 | 112.5 | 21.3 | 66.9 | 10.0 | 2.0 | 6.0 | 26.5 | 5.0 | 15.8 | 3.10 | 1.60 | 2.35 |
| 3 | 1-5-0 | 6.0 | 3.3 | 4.6 | 138.5 | 27.0 | 82.8 | 5.5 | 2.0 | 3.8 | 22.5 | 8.0 | 15.3 | 2.30 | 2.50 | 2.40 |
| 4 | 1-14-0 | 4.0 | 3.3 | 3.7 | 66.5 | 7.5 | 37.0 | 2.0 | 0.5 | 1.3 | 15.5 | 2.0 | 8.8 | 1.45 | 0.20 | 0.83 |
| 5 | 1-16-0 | 6.0 | 4.5 | 5.3 | 192.0 | 42.0 | 117.0 | 7.0 | 5.5 | 6.3 | 31.5 | 10.0 | 20.8 | 3.10 | 4.70 | 3.90 |
| 6 | 1-1001-0 | 4.5 | 5.3 | 4.9 | 81.0 | 22.8 | 51.9 | 3.5 | 1.0 | 2.3 | 17.5 | 4.0 | 10.8 | 1.85 | 1.65 | 1.75 |
| 7 | 1-1029-0 | 6.5 | 5.5 | 6.0 | 139.5 | 32.0 | 85.8 | 5.5 | 1.0 | 3.3 | 21.0 | 5.5 | 13.3 | 2.60 | 2.85 | 2.73 |
| 8 | 2-1020-0 | 6.5 | 4.5 | 5.5 | 183.5 | 28.5 | 106.0 | 7.0 | 2.5 | 4.8 | 28.5 | 6.5 | 17.5 | 3.40 | 3.05 | 3.23 |
| 9 | 3-1-0 | 6.0 | 4.3 | 5.1 | 153.0 | 48.8 | 100.9 | 5.5 | 6.0 | 5.8 | 25.5 | 12.0 | 18.8 | 2.85 | 3.65 | 3.25 |
| 10 | 3-4-0 | 4.0 | 4.3 | 4.1 | 108.0 | 11.5 | 59.8 | 4.0 | 1.5 | 2.8 | 27.0 | 3.0 | 15.0 | 1.80 | 0.75 | 1.28 |
| 11 | 3-1041-0 | 4.0 | 2.3 | 3.1 | 74.0 | 8.3 | 41.1 | 3.5 | 0.0 | 1.8 | 18.0 | 3.0 | 10.5 | 2.05 | 4.10 | 3.08 |
| 12 | 3-1042-0 | 7.0 | 4.0 | 5.5 | 157.5 | 7.0 | 82.3 | 7.5 | 1.0 | 4.3 | 23.0 | 2.5 | 12.8 | 2.85 | 1.25 | 2.05 |
| 13 | 4-4-0 | 4.0 | 5.0 | 4.5 | 99.5 | 29.0 | 64.3 | 8.0 | 3.0 | 5.5 | 25.5 | 5.5 | 15.5 | 2.50 | 1.30 | 1.90 |
| 14 | 4-14-0 | 4.0 | 3.0 | 3.5 | 65.5 | 7.0 | 36.3 | 3.0 | 0.5 | 1.8 | 17.5 | 2.5 | 10.0 | 2.20 | 0.50 | 1.35 |
| 15 | 451-0 | 6.5 | 5.8 | 6.1 | 151.0 | 63.3 | 107.1 | 7.0 | 3.5 | 5.3 | 23.0 | 11.5 | 17.3 | 3.30 | 4.75 | 4.03 |
| 16 | 451037-0 | 3.0 | 2.5 | 2.8 | 57.0 | 4.5 | 30.8 | 3.5 | 0.0 | 1.8 | 19.5 | 1.5 | 10.5 | 1.35 | 0.20 | 0.78 |
| 17 | 461002-0 | 3.0 | 6.3 | 4.6 | 67.0 | 10.8 | 38.9 | 4.5 | 1.5 | 3.0 | 20.0 | 1.5 | 10.8 | 1.70 | 1.30 | 1.50 |
| 18 | 461024-0 | 4.5 | 5.0 | 4.8 | 114.5 | 50.0 | 82.3 | 5.5 | 7.5 | 6.5 | 24.0 | 10.0 | 17.0 | 2.15 | 4.05 | 3.10 |
| 19 | 461026-0 | 4.0 | 5.8 | 4.9 | 82.5 | 26.3 | 54.4 | 5.5 | 1.5 | 3.5 | 20.5 | 4.5 | 12.5 | 2.60 | 2.85 | 2.73 |
| Check No. 1[c] | | 5.0 | 5.0 | 5.0 | 131.9 | 35.6 | 83.8 | 8.6 | 4.5 | 6.6 | 26.5 | 7.0 | 16.8 | 3.27 | 2.88 | 3.08 |
| Check No. 2[c] | | 3.9 | 2.5 | 3.2 | 76.5 | 11.9 | 44.2 | 4.4 | 1.3 | 2.9 | 19.8 | 3.9 | 11.9 | 2.32 | 1.35 | 1.84 |
| Interaction—strains x locations: F[d] | | 1.16 | | | 3.19** | | | 2.90** | | | 0.99 | | | 1.49 | | |
| Comparison of strains (excluding checks): F[d] | | 1.60 | | | 6.03** | 3.91** | | 3.45** | 7.54** | | 3.58** | | | 3.48** | | |
| L.S.D.[e] | | -- | -- | NS | 50.3 | 25.5 | -- | 3.2 | 2.2 | -- | -- | -- | 5.2 | -- | -- | 1.47 |

[a]Relative vigor of foliage approximately 1 month after thinning; U.S. 216 check = 5.
[b]Product of relative foliage vigor x number of living plants per plot, approximately 1 month after thinning.
[c]Checks systematically arranged; 8 plots of each at each location; data not analyzed statistically:
Check No. 1—U.S. 216 moderately resistant.
Check No. 2—S.P.I. No. 1-9-00; susceptible.
[d]Asterisks used to denote significance of interaction or of strain differences, according to F-test, as follows:
* —5 percent level of significance.
**—1 percent level of significance.
[e]Difference between strains required for significance at 5 percent level. "NS" is used where F-test indicates non-significance of differences.

Table 2.—Black-root reaction of progenies of 43 open-pollinated sugar beet plants selected under severe black-root exposure; tests conducted at Blissfield, Michigan, and Waseca, Minnesota, 1947; results given as 2-plot averages for each location.

| Strain | | Foliage vigor reading[a] | | | Estimated quantity of foliage per plot[b] | | | Harvest results (per plot) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Healthy roots | | | Total roots | | | Total weight of roots | | |
| Temp. No. | S.P.I. No. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. |
| | | | | | | | | No. | No. | No. | No. | No. | No. | lb. | lb. | lb. |
| 20 | 46A16-6H | 7.0 | 5.0 | 6.0 | 122.5 | 45.0 | 83.8 | 7.0 | 5.5 | 6.3 | 17.5 | 8.5 | 13.0 | 2.80 | 5.80 | 4.30 |
| 21 | 46A16-16G | 6.5 | 5.0 | 5.8 | 140.5 | 37.5 | 89.0 | 5.0 | 4.0 | 4.5 | 22.5 | 7.5 | 15.0 | 3.85 | 4.30 | 4.08 |
| 22 | 46A16-75F | 8.0 | 6.3 | 7.1 | 220.0 | 55.0 | 137.5 | 7.0 | 6.0 | 6.5 | 27.5 | 9.5 | 18.5 | 4.25 | 6.85 | 5.55 |
| 23 | 46A16-79F | 7.5 | 5.5 | 6.5 | 179.0 | 52.8 | 115.9 | 6.5 | 4.5 | 5.5 | 24.0 | 8.5 | 16.3 | 4.35 | 9.15 | 6.75 |
| 24 | 46A16-82F | 6.0 | 5.0 | 5.5 | 138.0 | 49.3 | 93.6 | 5.5 | 3.5 | 4.5 | 24.0 | 9.0 | 16.5 | 2.75 | 4.60 | 3.68 |
| 25 | 46A16-104E | 8.0 | 5.5 | 6.8 | 216.0 | 44.0 | 130.0 | 9.0 | 5.5 | 7.3 | 27.0 | 8.0 | 17.5 | 5.30 | 6.25 | 5.78 |
| 26 | 46A16-108C | 6.5 | 4.5 | 5.5 | 153.5 | 17.0 | 85.3 | 5.5 | 2.0 | 3.8 | 23.5 | 3.5 | 13.5 | 3.00 | 1.50 | 2.25 |
| 27 | 46A16-123H | 7.0 | 6.3 | 6.6 | 161.0 | 65.5 | 113.3 | 5.5 | 7.0 | 6.3 | 22.5 | 8.5 | 15.5 | 3.40 | 8.05 | 5.73 |
| 28 | 46A16-165G | 8.0 | 6.8 | 7.4 | 172.0 | 75.0 | 123.5 | 8.0 | 5.5 | 6.8 | 21.5 | 10.0 | 15.8 | 4.30 | 6.70 | 5.50 |
| 29 | 46A16-172H | 8.0 | 6.0 | 7.0 | 204.0 | 45.0 | 124.5 | 8.0 | 5.0 | 6.5 | 26.0 | 7.5 | 16.8 | 3.20 | 5.30 | 4.25 |
| 30 | 46A16-225H | 6.5 | 6.8 | 6.6 | 99.0 | 56.8 | 77.9 | 4.5 | 7.0 | 5.8 | 15.5 | 9.0 | 12.3 | 2.40 | 8.75 | 5.58 |
| 31 | 46A16-239E | 7.5 | 5.0 | 6.3 | 194.5 | 42.5 | 118.5 | 9.0 | 6.5 | 7.8 | 25.5 | 8.5 | 17.0 | 4.00 | 5.95 | 4.98 |
| 32 | 46A16-242H | 7.5 | 6.5 | 7.0 | 186.0 | 91.0 | 138.5 | 6.5 | 10.0 | 8.3 | 25.5 | 14.0 | 19.8 | 3.30 | 11.45 | 7.38 |
| 33 | 46A16-254D | 8.5 | 3.8 | 6.1 | 219.5 | 12.5 | 116.0 | 9.5 | 1.5 | 5.5 | 25.5 | 3.5 | 14.5 | 3.90 | 1.55 | 2.73 |
| 34 | 46A16-338 | 7.0 | 5.3 | 6.1 | 169.0 | 47.5 | 108.3 | 5.5 | 3.0 | 4.3 | 26.5 | 9.0 | 17.8 | 3.15 | 4.55 | 3.85 |
| 35 | 46A17-373 | 7.0 | 5.8 | 6.4 | 169.0 | 92.3 | 130.6 | 5.5 | 5.5 | 5.5 | 24.5 | 16.0 | 20.3 | 2.70 | 8.25 | 5.48 |
| 36 | 46A17-377 | 7.5 | 3.0 | 5.3 | 187.5 | 16.8 | 102.1 | 9.0 | 3.0 | 6.0 | 26.0 | 5.5 | 15.8 | 4.05 | 1.95 | 3.00 |
| 37 | 46A17-379 | 8.0 | 6.5 | 7.3 | 184.0 | 22.3 | 103.1 | 11.0 | 2.0 | 6.5 | 22.5 | 3.5 | 13.0 | 4.55 | 2.95 | 3.75 |
| 38 | 46A17-387 | 7.0 | 4.5 | 5.8 | 210.0 | 36.0 | 123.0 | 5.0 | 4.5 | 4.8 | 30.0 | 7.5 | 18.8 | 3.50 | 5.00 | 4.25 |
| 39 | 46A17-407 | 6.5 | 4.0 | 5.3 | 175.0 | 34.0 | 104.5 | 7.0 | 3.5 | 5.3 | 26.5 | 5.5 | 16.0 | 3.20 | 3.25 | 3.23 |
| 40 | 46A17-420 | 7.5 | 4.5 | 6.0 | 206.0 | 13.5 | 109.8 | 8.0 | 1.5 | 4.8 | 27.5 | 3.0 | 15.3 | 3.60 | 2.05 | 2.83 |
| 41 | 46A17-421 | 7.5 | 5.3 | 6.4 | 180.5 | 61.5 | 121.0 | 7.5 | 5.0 | 6.3 | 25.0 | 12.5 | 18.8 | 3.40 | 9.05 | 6.23 |
| 42 | 46A17-422 | 7.5 | 6.0 | 6.8 | 232.5 | 28.5 | 130.5 | 5.5 | 3.0 | 4.3 | 31.5 | 5.0 | 18.3 | 3.50 | 3.35 | 3.43 |
| 43 | 46A17-438 | 7.5 | 6.8 | 7.1 | 226.5 | 51.3 | 138.9 | 5.5 | 3.0 | 4.3 | 30.0 | 7.0 | 18.5 | 3.40 | 4.70 | 4.05 |
| 44 | 46A17-440 | 7.0 | 6.0 | 6.5 | 161.0 | 23.0 | 92.0 | 5.0 | 2.5 | 3.8 | 22.5 | 3.5 | 13.0 | 2.35 | 1.10 | 1.73 |
| 45 | 46A17-443 | 7.5 | 5.5 | 6.5 | 198.5 | 46.8 | 122.6 | 10.5 | 6.0 | 8.3 | 27.0 | 8.0 | 17.5 | 4.90 | 7.00 | 5.95 |
| 46 | 46A17-444 | 7.0 | 6.0 | 6.5 | 175.0 | 93.3 | 134.1 | 4.5 | 7.5 | 6.0 | 25.5 | 14.0 | 19.8 | 3.10 | 6.65 | 4.88 |
| 47 | 46A17-447 | 6.5 | 5.3 | 5.9 | 138.0 | 20.5 | 79.3 | 5.0 | 2.5 | 3.8 | 21.5 | 3.0 | 12.3 | 2.60 | 1.65 | 2.13 |
| 48 | 46A17-468 | 8.0 | 6.3 | 7.1 | 192.0 | 50.3 | 121.1 | 7.0 | 2.5 | 4.8 | 24.5 | 8.0 | 16.3 | 4.20 | 4.85 | 4.53 |

Table 2—Continued

| Strain | | Foliage vigor reading[a] | | | Estimated quantity of foliage per plot[b] | | | Harvest results (per plot) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Healthy roots | | | Total roots | | | Total weight of roots | | |
| Temp. No. | S.P.I. No. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. | Bliss. | Was. | Aver. |
| | | | | | | | | No. | No. | No. | No. | No. | No. | lb. | lb. | lb. |
| 49 | 46A17-471 | 7.5 | 6.8 | 7.1 | 194.0 | 50.3 | 122.1 | 8.0 | 3.5 | 5.8 | 27.0 | 7.5 | 17.3 | 3.70 | 5.85 | 4.78 |
| 50 | 46A17-472 | 7.5 | 4.8 | 6.1 | 163.0 | 26.3 | 94.6 | 7.5 | 3.0 | 5.3 | 21.0 | 4.5 | 12.8 | 3.70 | 3.10 | 3.40 |
| 51 | 46A17-475 | 7.5 | 6.3 | 6.9 | 207.5 | 32.5 | 120.0 | 9.0 | 3.5 | 6.3 | 27.5 | 5.5 | 16.5 | 4.55 | 3.85 | 4.20 |
| 52 | 46A18-521 | 6.0 | 4.0 | 5.0 | 142.0 | 3.5 | 72.8 | 8.5 | 1.0 | 4.8 | 23.0 | 1.0 | 12.0 | 2.70 | 0.45 | 1.58 |
| 53 | 46A18-530 | 6.5 | 4.8 | 5.6 | 172.5 | 17.8 | 95.1 | 8.0 | 2.5 | 5.3 | 27.0 | 4.0 | 15.5 | 3.50 | 1.95 | 2.73 |
| 54 | 46A18-544 | 6.0 | 3.3 | 4.6 | 150.0 | 41.5 | 95.8 | 9.0 | 4.0 | 6.5 | 25.0 | 9.0 | 17.0 | 4.00 | 4.10 | 4.05 |
| 55 | 46A18-548 | 5.0 | 5.6 | 5.3 | 131.0 | 32.5 | 81.8 | 6.0 | 2.5 | 4.3 | 25.5 | 5.0 | 15.3 | 3.10 | 3.50 | 3.30 |
| 56 | 46A18-555 | 4.5 | 3.0 | 3.8 | 111.0 | 18.8 | 64.9 | 7.5 | 4.0 | 5.8 | 25.5 | 6.5 | 16.0 | 2.65 | 3.80 | 3.23 |
| 57 | 46A18-576 | 5.5 | 4.3 | 4.9 | 135.5 | 15.3 | 75.4 | 4.5 | 3.0 | 3.8 | 24.0 | 3.5 | 13.8 | 2.60 | 2.75 | 2.68 |
| 58 | 46A18-594 | 4.5 | 5.6 | 5.0 | 113.0 | 14.0 | 63.5 | 6.5 | 1.0 | 3.8 | 25.5 | 2.0 | 13.8 | 2.60 | 1.10 | 1.85 |
| 59 | 46A18-611 | 5.5 | 5.8 | 5.6 | 150.0 | 22.3 | 86.1 | 8.5 | 3.0 | 5.8 | 27.5 | 4.0 | 15.8 | 3.40 | 2.70 | 3.05 |
| 60 | 46A18-619 | 5.5 | 4.8 | 5.1 | 115.5 | 19.3 | 67.4 | 4.5 | 3.0 | 3.8 | 21.0 | 4.0 | 12.5 | 2.20 | 1.75 | 1.98 |
| 61 | 46A18-632 | 6.5 | 4.8 | 5.6 | 149.5 | 28.3 | 88.9 | 6.5 | 5.0 | 5.8 | 23.5 | 7.0 | 15.3 | 3.50 | 3.90 | 3.70 |
| 62 | 46A18-633 | 4.5 | 3.0 | 3.8 | 94.5 | 21.8 | 58.1 | 5.5 | 2.5 | 4.0 | 21.0 | 7.5 | 14.3 | 2.15 | 3.40 | 2.78 |
| Check No. 1[c] | | 5.0 | 5.0 | 5.0 | 128.0 | 29.2 | 78.6 | 5.5 | 3.7 | 4.6 | 26.2 | 5.6 | 15.9 | 2.38 | 3.14 | 2.76 |
| Check No. 2[c] | | 3.3 | 2.1 | 2.7 | 55.9 | 4.4 | 30.2 | 1.1 | 0.4 | 0.8 | 16.7 | 1.8 | 9.3 | 1.10 | 0.76 | 0.93 |
| Interaction—strains x locations: F[d] | | 1.28 | | | 1.44 | | | 1.16 | | | 1.27 | | | 1.39 | | |
| Comparison of strains (excluding checks): F[d] | | 3.32** | | | 2.10** | | | 0.96 | | | 1.23 | | | 1.83** | | |
| L.S.D.[e] | | -- | -- | 1.4 | -- | -- | 44.5 | -- | -- | NS | -- | -- | NS | -- | -- | 2.95 |

[a]Relative vigor of foliage approximately 1 month after thinning; U.S. 216 check = 5.

[b]Product of relative foliage vigor x number of living plants per plot, approximately 1 month after thinning.

[c]Checks systematically arranged; 10 plots of each at Blissfield and 18 of each at Waseca; data not analyzed statistically:
Check No. 1—U.S. 216; moderately resistant.
Check No. 2—S.P.I. No. 1-9-00; susceptible.

[d]Asterisks used to denote significance of interaction or of strain differences, according to F-test, as follows:
**—1 percent level of significance.

[e]Difference between strains required for significance at 5 percent level. "NS" is used where F-test indicates non-significance of differences.

Foliage vigor readings and stand counts were made approximately 1 month after thinning. The product of the vigor reading and the stand count obtained for each plot was used as an estimate of total quantity of foliage in that plot. At harvest, roots were segregated into " apparently healthy" and "apparently diseased" classes, the latter showing obvious tip rot of the main or tap root, severe sprangling, or severe stunting. The roots in each class were counted and the total weight of roots, including crowns, was recorded.

## Results

The data obtained from the set of 19 leafspot-resistant strains at both locations are summarized in table 1, and comparable data for the set of 43 progenies of mother beets selected under black-root conditions are presented in table 2. Stand counts are omitted because of the fact that they differed only slightly from total roots harvested. The two groups of columns in these tables considered most useful for evaluation of the strains as to black-root resistance are 1.—estimated quantity of foliage and 2.—total weight of roots. It must be acknowledged that the strains tested differed in their inherited vigor or ability to grow, under disease-free conditions. However, under the conditions of these tests, blackroot is considered the chief factor limiting production of both roots and foliage. Leafspot occurred only in trace amounts.

As shown by the F-test in both tables, there were highly significant differences between strains in estimated quantity of foliage and in total weight of roots. Certain strains, especially among those having a background of black-root-resistance selection (table 2), were substantially better than the moderately resistant check No. 1, U.S. 216. In this connection it is of interest to compare the performance of this strain with that of check No. 2, 1-9-00. The latter variety has consistently produced a higher tonnage of roots and sucrose than U.S. 216 under irrigation in western sugar beet areas where black root was not a factor. The relatively poor showing of check No. 2 in this experiment is attributed to its susceptibility to black root. The relative performance of the two checks and of certain resistant progenies listed in table 2 is further illustrated in figures 1 and 2.

Comparison of the Blissfield results with those obtained at Waseca reveals a strong tendency toward similar strain reaction at the two locations. This general tendency is shown by the F values for interaction of strains x locations. In the larger set of material (table 2), the F test indicates non-significance of interaction for each of the five attributes studied, and in the smaller set (table 1), non-significant interaction is shown for three of the five attributes. However, it should be noted in the latter table that strains x locations interaction was highly significant for estimated quantity of foliage and for number of healthy roots. One of the strains contributing heavily to this interaction is number 12 which was among the three poorest in quantity of foliage at Waseca and well above the resistant check at Blissfield. In number of healthy roots, strain

number 2 was highest in the set of 19 at Blissfield and below average at Waseca. In table 2, although none of the strains x locations interactions are significant, certain rather striking contradictions are evident. For example, strain number 42 was substantially below average in quantity of foliage at Waseca and highest in the entire set of 43 strains at Blissfield. Conversely, number 32 was below average at Blissfield, in total weight of roots, and highest on the list at Waseca.

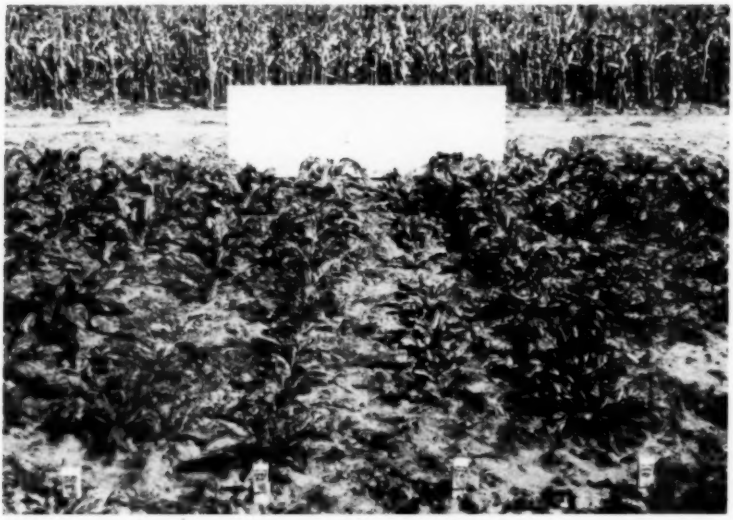
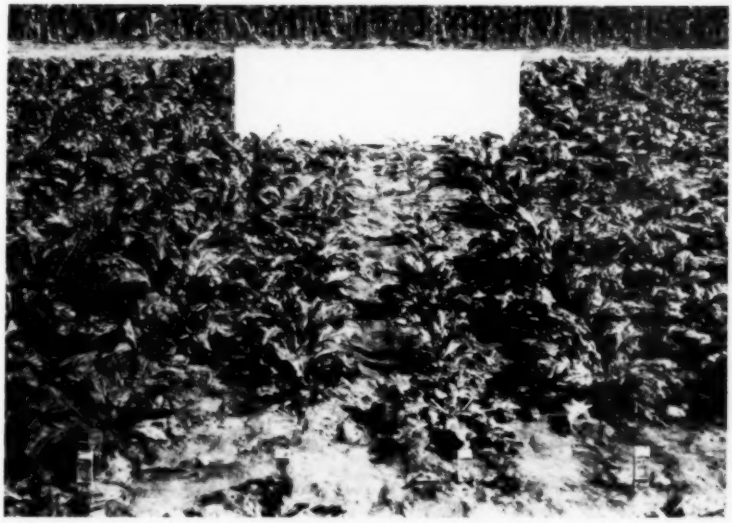


Figure 1.—Comparison of two breeding strains of sugar beets with resistant and susceptible checks under black-root conditions, Blissfield, Michigan, October 1, 1947. Left to right: strain 24, Check 1 (U.S. 216), Check 2 (1-9-00), and strain 25.

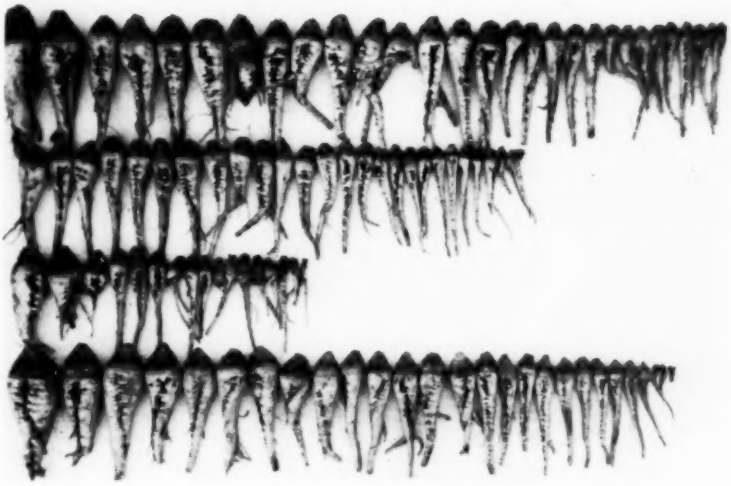
The general tendency for strains to react similarly under black-root conditions at the two locations is encouraging. However, the contradictory performance of certain strains emphasizes the need for caution in the appraisal of breeding material or prospective varietal releases without adequate testing in various localities and under different conditions of disease exposure.

## Summary

Sixty-two strains of sugar beets, occurring in sets of 19 and 43 respectively, and varying considerably in black-root resistance, were grown under relatively severe black-root exposure at Blissfield, Michigan, and Waseca, Minnesota, with two replications at each location. Approximately 1 month after thinning, strain comparisons were made in foliage vigor and in estimated quantity of foliage per plot. At harvest, comparisons were



A



B

Figure 2.—Comparison of two sugar beet breeding strains with resistant and susceptible checks under black-root conditions, Blissfield, Michigan, 1947. A—left to right: strain 22, Check 1 (U.S. 216), Check 2 (1-9-00), and a strain not included in this report because of insufficient replication; October 1. B—top to bottom: all roots from the four respective 1-row, 20-foot plots shown in A; at harvest, October 16.

made in number of healthy roots, total number of roots, and total weight of roots per plot.

In the 19-strain group, the interaction of strains x locations was highly significant for quantity of foliage and for number of healthy roots. Otherwise, strains x locations interaction was not significant for any of the above attributes in either of the two sets of strains.

These results showed a general tendency for strains to react similarly at the two locations. However, the contradictory reaction of certain strains emphasizes the importance of testing promising material in various localities.

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# Strains of Sugar Beets Extremely Resistant to Bolting

J. S. McFarlane, Charles Price and F. V. Owen[1]

The development of seedstalks, known as bolting, is an undesirable character in sugar beets when the crop is grown for sugar production. In most parts of the country bolting is not a serious problem because the commercial varieties are sufficiently resistant when planted in the spring. However, in certain sections of California it is desirable to plant a portion of the crop in the early winter or fall months. Of the curly-top resistant varieties only U.S. 15 and U.S. 56 are sufficiently non-bolting for December plantings and even these varieties ordinarily bolt severely when planted in October and November.

Preliminary work in developing extremely non-bolting varieties has been in progress at Salt Lake City, Utah, and Riverside, California, during the past several years. Selections of individual non-bolting beets were made from open-pollinated populations. These individuals were then hybridized or selfed and further non-bolting selections made from the resulting progenies. Several of the more promising hybrids and inbreds were tested for non-bolting in strip plantings at Riverside, California, in 1946. The results are given in table 1.

**Table 1.—Percentage of bolters from a planting made August 20, 1946, at Riverside, California.**

| Strain | Plants observed | Plants bolting April 17* |
|---|---|---|
| | Number | Percent |
| U.S. 15 | 456 | 53.7 |
| U.S. 56 | 446 | 30.9 |
| R. & G. Old Type | 458 | 57.0 |
| S.L. 553 | 396 | 5.3 |
| Inbred 4201 | 423 | 21.3 |
| Inbred 4738 | 398 | 0.5 |
| S.L. 453 x 4738 | 430 | 1.9 |
| 4109 MS x U.S. 56 | 430 | 30.5 |
| 5107 MS x U.S. 56 | 436 | 42.9 |

*Bolting as used here is the appearance of a seedstalk whether or not flowering is involved.

In this test the newly developed variety U.S. 56 bolted 30.9 percent and was superior to U.S. 15, which bolted 53.7 percent. Strain S.L. 553, a non-bolting selection from a hybrid between two individual beets, bolted only 5.3 percent. The seedstalks in S.L. 553 were short and vegetative in contrast to the tall, heavy seed-producing type found in the susceptible varieties. Inbred 4201, which was still heterozygous for bolting resistance, bolted 21.3 percent and inbred 4738 bolted 0.5 percent. A hybrid between S.L. 453, which was an earlier increase of S.L. 553 and inbred 4738, bolted

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1.9 percent. The data indicate that resistance to bolting is recessive and are in agreement with those of Abegg (1)[2] and Owen, et al. (2). Two male-sterile hybrids included in the test were similar in bolting behavior to U.S. 56 and U.S. 15. Male-sterile 4109 represented a group of male-sterile plants from U.S. 56. Male-sterile 5107 was from U.S. 56 x U.S. 15.

Yields or sugar percentages were not determined from the Riverside planting. Data from a November planting at Shafter, California, indicated that the yielding ability of a male-sterile hybrid between (U.S 56 x U.S. 15) MS and inbred 4201 was superior to either that of U.S. 56 or U.S. 15.

Figure 1.—Comparison of the bolting habit of inbred 4201 (left) and U.S. 15 (right) in an overwintered field planting at Salt Lake City, Utah. The planting was made August 17, 1946, and photographed June 12, 1947.

In addition to the strip plantings described above a large number of hybrids and inbreds were planted in small observational plots at Salt Lake City, Utah, and Riverside, California. Promising non-bolting types were selected for further testing and for use in the hybridization work. A comparison between a promising inbred and U.S. 15 is shown in figure 1. Included in these plantings were hybrids involving strains highly resistant to curly top.

Seed of these extremely non-bolting strains was successfully produced in overwintered field plantings at Salt Lake City. Plantings made in August were protected from cold injury by a light covering of either manure or soil during the winter months. All plants bolted the following spring and summer. Similar material planted in August at Medford, Oregon, failed to bolt completely.

Although it is unlikely that any of the non-bolting strains included in the above tests are satisfactory as commercial varieties, their value as breed-

[2]The numbers in parentheses refer to literature cited.

ing material was well demonstrated. Extremely non-bolting commercial varieties should be a possibility in the near future.

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# Inheritance of Bolting Resistance

W. B. Marcum[1]

A study was inaugurated in 1945 by the Spreckels Sugar Company for the purpose of investigating the inheritance of bolting resistance in the progenies of various hybrid crosses. For the purpose of illustration, this report will be confined to a portion of that study in which crosses were made between bolting resistant selections of Improved U.S. 15 and cytoplasmic male-sterile selections of S.L. 5107, a United States Department of Agriculture variety which bolts readily under suitable conditions.

A number of non-bolting selections were made by Dr. LeRoy Powers from a seed field of Improved U.S. 15 growing in Medford, Oregon in 1945. These roots were refrigerated at a temperature of 4 degrees centigrade for approximately 60 days and transplanted into an isolated plot to furnish the male parent for the subsequent crosses of this test. Seed of S.L. 5107 was planted in the isolated plot alongside the non-bolting selections. During anthesis the cytoplasmic male-sterile plants were used as the female parent and the male-fertile plants of S.L. 5107 were rogued out. Controlled pollination crosses were made between these two varieties by means of both paper bags and doubled-cloth sugar bags. In addition, crosses were made within the non-bolting selections and all open-pollinated seed of this strain was saved.

[1]Spreckels Sugar Company.

**Table 1.—The percentage of bolters obtained from hybrid crosses.**

| Progeny | Bolting % |
|---|---|
| 2012—1 | 23.3 |
| 2012—1A | 28.5 |
| 2012—7 | 20.4 |
| 2012—10 | 20.4 |
| 2012—12 | 28.4 |
| 2012—14 | 16.4 |
| 2012—15 | 17.4 |
| 2012—17 | 22.7 |
| 2012—18 | 25.3 |
| 2012—22 | 26.7 |
| 2012—32 | 9.5 |
| 2012—45 | 4.9 |
| 2012—45A | 2.7 |
| 2012—51 | 28.5 |
| 2012—52 | 21.3 |
| 2012—66 | 28.5 |
| 2012—67 | 6.6 |
| 2012—69 | 14.4 |
| Average of progeny | 19.2 |
| Average of female parent S.L. 5107 (5 repl.) | 58.7 |
| Average of male parent 462001 (35 repl.) | 1.6 |
| Average of Improved U.S. 15 (32 repl.) | 14.4 |

A progeny test of the resultant strains from this isolated plot was made in October of 1946 under conditions which were thought to be favorable for bolting. These bolting counts were made the following Spring.

In comparing the bolting percentages of the progeny from the hybrid crosses with the bolting percentages of the parents, it can be readily seen that the progeny all contained the factor for medium resistance to bolting. As a result of this test it would appear that the bolting resistance of the male parent is a dominant characteristic.

# Utilization of Male Sterility in Breeding Superior-Yielding Sugar Beets

F. V. Owen[1]

It has now been well demonstrated that hybrid sugar beets can be produced which are superior in yielding ability to the curly-top-resistant varieties now in commercial use. Data obtained from male-sterile hybrids in 1945 (3)[2] show a significant increase in yield over standard commercial varieties. These results were repeated in 1946, and in 1947 still better results were obtained with more recent hybrids. The seed supplies of these male-sterile hybrids have not as yet been produced in commercial quantities but there is a possibility of this in the not too distant future.

Male sterility in sugar beets may be inherited in different ways. The type of male sterility most useful to the breeder is inherited cytoplasmically. Pure cytoplasmic inheritance has the advantage of being simpler than Mendelian inheritance as far as the rules of superficial analysis are concerned. However, the underlying basis of cytoplasmic inheritance is not fully understood and it has only recently attracted widespread interest among American geneticists. In the present paper it will suffice to deal with the simple rules of the inheritance of the cytoplasmically inherited male sterility that apply to practical breeding problems.

Male-sterile beets are represented by the designation MS. These beets are fertile as females but completely sterile as males and they can, therefore, be used only as females in hybridization work. Artschwager (1) has recently described the abnormal development within the anther responsible for the male sterility.

## How Male Sterility is Inherited

Male sterility, to be useful in breeding work, must be easily obtained. Accurate predictions regarding the constitution of progenies from respective crosses are particularly important. Male sterility is most useful when progenies can be produced in which 100 percent of the beets are completely male-sterile. Inheritance studies have shown that such progenies are not only possible but are also common among controlled crosses to the male-sterile beets. Unfortunately, some crosses to the male-sterile beets do not produce uniformly male-sterile offspring and genic effects have been recognized (2) which appear to modify the expression of the cytoplasmic inheritance. These complications make it necessary to conduct extensive tests to determine which progenies can be depended upon to produce completely male-sterile offspring.

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[2]The numbers in parentheses refer to literature cited.

Three general types of pollen parents will be designated O, I, and II. These pollen parents are normal hermaphrodite beets and can be used either as females or as pollen parents. Here they will be considered principally as pollen parents. The O, I, and II beets can not be distinguished by their appearance; they differ only in breeding behavior (table 1).

**Table 1.—Breeding behavior of three genotypes O, I, and II.**

| Parents | | | Offspring |
|---|---|---|---|
| ♀ | | ♂ | |
| MS | × | O | all MS |
| MS | × | I | mostly MS (5 to 30 percent semi-MS) |
| MS | × | II | 50 percent MS<br>25 percent semi-MS<br>25 percent more or less normal |

In successive backcrosses to type O, male sterility is inherited entirely through the female parent as shown in figure 1.

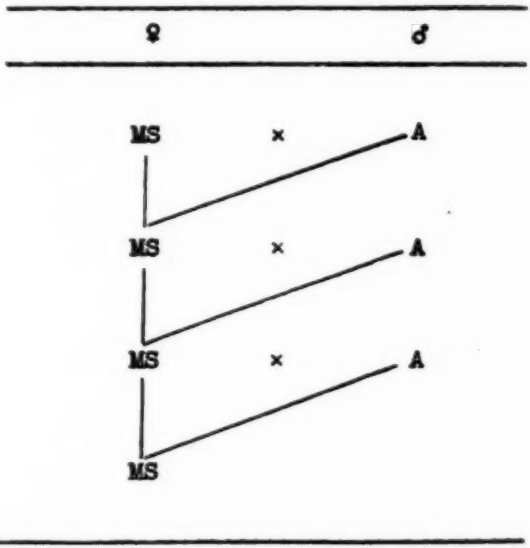


Figure 1.—Inheritance of male sterility in successive backcrosses to type O; all offspring are male-sterile.

Succeeding generations of MS females crossed to type O beets are all completely male-sterile. Type O is the desirable type when one wishes to propagate male-sterile beets. Types I and II are undesirable. To avoid these undesirable types preliminary crosses are necessary so that the objectionable types may be discarded. In some commercial sugar beet varieties about 50 percent of the beets are type O. To distinguish and preserve these desirable type O beets, they must be clonally propagated or else they must

be self-pollinated. A third method of crossing two self-sterile beets in pairs can be used. Preservation of type O beets by self-pollination has many advantages. Besides preservation of the desirable O type, selfing also makes possible a new and powerful approach to the problem of isolating superior genotypes of sugar beets.

## Methods of Hybridization

There are several methods of hybridization available to the sugar beet breeder in the utilization of male sterility. First, it is necessary to rogue out undesirable beets that are not completely male-sterile. The first populations of male-steriles may be mixed with intermediate or semi-male-sterile beets because of type I and II pollen parents. In seed isolations roguing can be accomplished before the flowers open by using a sharp knife and cutting into well-developed floral buds. After building up reliable male-sterile populations it is possible to consider extensive backcrossing procedures always utilizing the male-sterile as the female parent.

The curly-top-resistant inbred sugar beet designated CT9 was the first inbred to be extensively investigated with regard to hybridization with male-steriles. The first hybrids were made with CT9 as the pollen parent. These hybrids gave such promising results that a series of backcrosses to the inbred parent were initiated.

The backcrossing procedure is illustrated in figure 2.

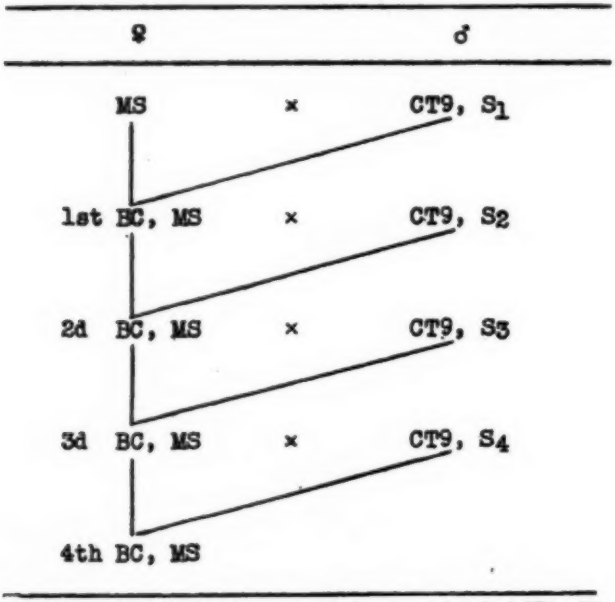


Figure 2.—Inheritance of male sterility in successive backcrosses to the inbred CT9. BC indicates backcross generation while $S_1$, $S_2$, etc., indicate generation of selfing.

The second and third backcross to the male-sterile produced MS beets strongly resembling the CT9 inbred. A fourth backcross was produced in 1947. The third and fourth backcross generations may, for practical purposes, be considered MS equivalents of CT9.

After an MS equivalent of CT9 was obtained, it was possible to utilize the CT9 genotype as a female parent. Formerly it could be utilized only as a pollen parent. High-yielding hybrids were produced regardless of whether CT9 was used as the pollen parent or whether the male-sterile equivalent of CT9 was used as a female parent. In several replicated tests in 1947 all CT9 hybrids produced more sugar per acre than standard commercial varieties. In some instances this increase amounted to over 20 percent.

The hybrids with CT9 so far produced are similar to what have been termed top crosses in corn, in other words, one of the parents was an open-pollinated variety. Hybrids between properly selected inbred lines should be superior to top crosses. Three-way hybrids between inbred sugar beets may have possibilities. This involves the production of the male-sterile equivalent of one of the lines and the selection of a second inbred of type O. The scheme is illustrated in figure 3.

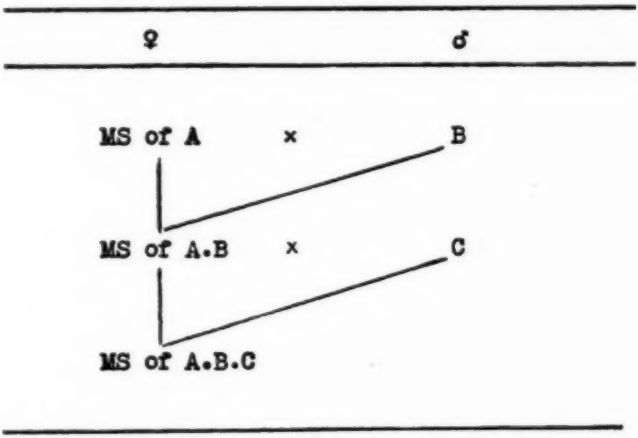


Figure 3.—Production of a three-way hybrid from the inbreds A, B, and C.

Male sterility may also be used to facilitate other desirable hybrids. Tetraploid sugar beets have now been produced by several investigators. Hybrids between tetraploids and the usual diploids produce triploids. Excellent vigor has been obtained in preliminary experiments with these

triploid hybrids. This and other types of hybridization work can be facilitated by utilization of male sterility.

## Male Sterility in Relation to Inbreeding

The manner in which inbred lines can be utilized with male sterility reverses much of the line of thought in sugar beet breeding. Homozygous inbreds, which heretofore have been interesting but without value, suddenly become of great value. Inbred lines like CT9 are so highly self-fertile that they cannot be hybridized directly. When beets from two of these lines were grown together they did not hybridize more than about 10 percent and sometimes much less than this. This high degree of self-fertility, together with the resulting homozygosity and lack of vigor, makes the inbred lines worthless within themselves. Their value, like that of the corn inbreds, is dependent upon their yield prepotency. All inbreds are not expected to have high-yield prepotency. The breeder's task is to sort out the good from the bad and to select inbreds for hybridization which have high-combining ability or yield prepotency. Useful inbreds must also possess desired qualitative characters such as disease resistance, root shape, etc. Inbreeding greatly facilitates the attainment of these desired qualitative characters. By means of hybridization through male sterility, inbred lines of sugar beets can be utilized in much the same way that inbred lines of corn have been so widely utilized.

## Summary

Hybridization in sugar beets by means of male sterility has promise of being a practical procedure because of the fact that the inheritance of certain types of male sterility follows relatively simple rules. These rules are simple because they are governed chiefly by cytoplasmic inheritance rather than by the more complex rules of Mendelian inheritance. The simple rules of cytoplasmic inheritance have made it possible to establish male-sterile equivalents of many curly-top-resistant strains and varieties and of some inbred lines. The method does not work with all inbred lines because some beets apparently carry genes which modify the expression of the cytoplasmic inheritance. It is necessary to avoid these objectionable genes by means of progeny tests. As a rule about 50 percent of beets selected at random do not carry the objectionable genes. The curly-top-resistant inbred line CT9 is an example of a relatively desirable inbred.

Different methods of hybridization with CT9 have been illustrated. It is important now to develop more and better inbred lines. It is also important to explore the possibility of obtaining superior hybrids by bringing together genotypes from diverse origins. Cytoplasmically inherited male sterility facilitates hybridization work of many kinds. It is an invaluable tool in genetic investigations and also has promise of being useful in producing high-yielding hybrids on a commercial scale.

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# A Preliminary Test of the Efficiency of a Modified Gamete-Selection Method for Breeding Sugar Beets

H. E. Brewbaker and R. R. Wood[1]

It was pointed out by Brewbaker and McGreevy (1)[2] in 1938 that the family-breeding methods employed by The Great Western Sugar Company for varietal improvement had resulted in a similar pattern to that observed in corn (2). When these methods were adopted in 1925, improvement in yield of roots and total sugar was fairly rapid, with the percentage of sugar remaining fairly stable. Since 1931, however, improvement became increasingly difficult to obtain and it was concluded that the family- or progeny-test method had definite limitations for continued improvement of the sugar beet except as it might be used to increase resistance to such diseases as leafspot and curly top, and thereby to improve yielding ability and quality.

More recently, the family-breeding method has been applied with moderate success in breeding for resistance to curly top in the northern Wyoming and Montana districts. Since this work was started in 1942, improvement in yielding ability was anticipated for a few generations of what might be considered the adaptation phase.

Some of the earlier work leading up to the more recently developed gamete-selection method was done by Sprague (4) who advocated early testing of the combining ability of inbred lines of corn by top-crossing with a "tester" strain. Stadler (5) proposed the gamete-selection method, which applied to corn consists briefly of "direct testing of individual plants of a variety x inbred-line $F_1$ followed by a similar test-controlled selection in the $S_1$ of exceptional plants." This makes the gamete the unit of selection as based on the top-cross test. Richey (3) refers to these choice gametes as "superior" and any combination of such gametes as a "superlative" zygote. The importance of placing selection emphasis on the gamete rather than the zygote can be appreciated when one realizes that a frequency of 1 superior gamete in 100 would lead to 1 superlative zygote in 10,000. Selfing of an individual which produces superior gametes would, of course, result in the production of a much higher frequency of superlative individuals.

Our adaptation of the gamete-selection method to the sugar beet crop involves the use of a relatively large group (400 or more roots) of carefully selected individuals. A part of the inflorescence on each individual is

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[2]The numbers in parentheses refer to literature cited.

bagged for selfing and the remainder is permitted to open-pollinate with other plants in the group, the group itself constituting the "tester" line. The open-pollinated seed from those plants for which some selfed seed (50 or more) is available is used for immediate "top-cross" or progeny-test evaluation. The selfed seed from the plants represented as female parents of the 6 to 10 high-producing top-crosses is then planted for selection of so-called superlative individuals, which are to be immediately grouped together for two or more successive mass increases into commercial proportions.

## Materials and Methods

In 1943, selection was made from a Colorado increase of the curly-top-resistant variety U.S. 22. Some 408 roots were quartered, the four quarters from each root being planted at random within the group. This was done to increase seed production and the opportunity for wider source of male gametes for each female individual. All plants were bagged for selfing. Open-pollinated seed and bagged branches were harvested from a total of 403 roots, the quarters of each original root being collected together. The open-pollinated seed from each individual which produced 50 or more selfed seed was planted in a progeny test of triple lattice design with 6 replications for each family. A total of 168 strains were included in this test.

Selections were made in both the selfed and open-pollinated progeny of the ten strains which had the highest performance in production of total sugar per acre in the top-cross test. In the inbred phase, 43 selected roots were grouped together, the open-pollinated seed being harvested en masse and tested as B353. These same plants were also selfed as a source of good inbreds, this, however, being incidental to this particular study. In the open-pollinated phase the seed was also harvested en masse and tested as B355.

The performance tests were conducted at Billings, Huntley, and Hysham, Montana, in 1947. At the first two locations there were 9 replications of each variety and at the latter location 6 replications, or a total of 24 replications for each variety. Stand was good at all three locations, and no disease or hail injury of note was encountered.

## Experimental Results

The performance of the two numbers (B353 and B355) previously described, as compared with A53-42 (U.S. 22), follows:

| | Roots per Acre | | | | Sugar | | | |
|---|---|---|---|---|---|---|---|---|
| Acc. No. | B. | Hu. | Hy. | Ave. | B. | Hu. | Hy. | Ave. |
| | Tons | | | | Percent | | | |
| B353 | 23.62 | 19.45 | 23.97 | 22.35 | 14.93 | 18.45 | 16.39 | 16.59 |
| B355 | 22.64 | 18.59 | 22.98 | 21.40 | 15.26 | 18.10 | 16.41 | 16.59 |
| A53-42 | 22.41 | 18.05 | 22.02 | 20.83 | 15.46 | 18.19 | 17.29 | 16.98 |
| LSD 5 percent pt. | 1.52 | 1.10 | 1.61 | .94 | .73 | .59 | .88 | .41 |

| Acc. No. | Gross Sugar per Acre | | | | Beets per 100 Feet | | |
|---|---|---|---|---|---|---|---|
| | B. | Hu. | Hy. | Ave. | B. | Hu. | Hy. |
| | Pounds | | | | No. | | |
| B353 | 7053 | 7177 | 7857 | 7362 | 100 | 109 | 95 |
| B355 | 6910 | 6730 | 7542 | 7061 | 94 | 103 | 92 |
| A53-42 | 6929 | 6567 | 7615 | 7037 | 101 | 103 | 89 |
| LSD 5 percent pt. | 564 | 455 | 667 | 360 | | | |

In tonnage of beets per acre the difference between the averages for B353 and B355 is just significant at the 5 percent level. For percentage of sugar, both varieties appear to be nearly significantly below the standard (A53-42) at one location, there being no material differences at the other two locations. In sugar per acre the progeny of the selfed lines (B353) produced consistently more than either of the other lines at all three locations, the average falling only slightly below the 5 percent level for significance.

## Summary and Conclusions

On the basis of a preliminary test at three locations in 1947, lot B353, which was developed by an adaptation of the gamete-selection method, produced a slightly but significantly higher tonnage of roots at the 5 percent level than either the original variety (A53-42), or lot B355 which resulted from the older family-breeding method. In this respect the apparent superiority of B353 was consistent at all locations.

The differences in yield of roots were reflected in total sugar, although not quite sufficient to be significant at the 5 percent level. In percentage of sugar the differences were not very consistent and not significant.

While these results can hardly be considered as definite proof of the effectiveness of a modified gamete-selection method applied to sugar beets, they are encouraging enough to merit further test. On the basis of purely theoretical consideration this method would appear to be sound in principle and particularly well adapted for use with the sugar beet crop as an intermediate step between the broader mass and family-selection methods, and selection in self-fertilized lines.

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# Report on 1947 Tests of U. S. 215 x 216, and of Other Varieties from Sugar Beet Leafspot Resistance Breeding Investigations of the United States Department of Agriculture

G. H. Coons, Dewey Stewart, H. W. Bockstahler, G. W. Deming, J. G. Lill, S. B. Nuckols, O. E. Reece[1]

Agronomic evaluation tests were conducted in 1947 with U. S. 215 x 216 as represented by the variety, S.P. 4612-00, and with other varieties obtained in the federal leafspot resistance breeding project. Tests at a total of 17 locations were conducted by members of the staff of the Division in cooperation with State Agricultural Experiment Stations and by cooperators in the beet sugar industry. The cooperators in research organizations of the beet sugar industry who contributed data are Perc A. Reeve and Grant Nichol, Farmers and Manufacturers Beet Sugar Association (tests at Reece, Michigan, and Latty, Ohio), C. W. Doxtator, American Crystal Sugar Company (tests at Rocky Ford, Colorado, and Mason City, Iowa), C. E. Cormany and D. F. Peterson, Holly Sugar Corporation (test at Sidney, Montana), and H. E. Brewbaker and H. L. Bush, Great Western Sugar Company (tests at Brush and Longmont, Colorado).

The varieties included in the agronomic evaluation tests were as follows:

| | |
|---|---|
| S.P. 4511-00 | U. S. 215 x 216 4n. Seed of U. S. 215 4n (S.P. 3-1041-0) was mixed with an equal quantity of U. S. 216, 4n (S.P. 3-1042-0) to provide the planting stock for the seed field. |
| S.P. 451034-0 | Synthetic variety. Produced by direct increase of S.P. 3-1834-00. |
| S.P. 4610-00 | Synthetic variety. Seed of 6 inbred lines pooled to provide planting stock for the seed field. |
| S.P. 4611-00 | Single cross, U. S. 216 Imp. (S.P. 451-0) × S.P. 455-0, a leafspot resistant strain not related to U. S. 216. |
| S.P. 4612-00 | Single cross, U. S. 216 M. S. (S.P. 45102-01) × Imp. U. S. 215 (S.P. 4-14-0). |
| Nebraska 30 | Mass selected variety supplied by S. B. Nuckols. |
| S.P. 4-5-0 | "Synthetic Check." Seed of 9 European varieties pooled to furnish initial planting stock. Seed produced in New Mexico in 1944 by field-over-wintering method. |

[1]Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

"Local" Variety supplied by beet sugar companies for the purpose of relating performance of new candidates to currently used commercial stocks.

*Cercospora* leafspot was severe enough for readings to be made at Fort Collins (under sprinkler), Rocky Ford (under sprinkler), and Brush, Colorado; also at Mankato, Minnesota and Chatham, Ontario. At all other places, the disease was reported as 'limited', 'late', 'slight', 'negligible', or 'absent'. Apparently only at the locations at which readings were made did the disease produce effects on yield and quality.

The data for sugar per acre, root yield and sucrose percentage are summarized in tables 1, 2, and 3, the tests being grouped on basis of leafspot exposure. In table 4, the 17 tests in 1947 are compared with tests in previous years with same or related varieties (2, 3).[2]

In the 5 tests in which leafspot was a factor, Synthetic Check (4-5-0) in comparison with the leafspot-resistant varieties showed strong reduction in sugar per acre, in root yield and in sucrose percentage. Production of gross sugar was from about 9 to 15 percent lower and root yield was similarly reduced. Sucrose percentages were lower, numerically, by 1 to 3 percents. The local variety, G.W. 59, at Fort Collins (under sprinkler), was about equal to Synthetic Check, whereas at Brush, G.W. 85-45, a resistant variety, was significantly superior. Differences in sugar production between local and Synthetic Check were not significant at Rocky Ford, Colorado., Mankato, Minnesota, and Chatham, Ontario. At Rocky Ford, the local variety was significantly better in sucrose percentage. Nebraska 30, obtained by selection from European varieties, chiefly, was not significantly different from Synthetic Check. In general, all leafspot-resistant varieties made a favorable showing in comparison with the non-resistant sorts.

But these favorable showings for the resistant varieties were not maintained in the tests in which leafspot was of minor importance. Synthetic Check without disease was, as in 1946, relatively high in tonnage and in sucrose. Varieties produced by breeding work of the beet sugar companies were usually not significantly different from it in the production of sugar per acre. In two cases they were significantly lower. U. S. 215 x 216 Commercial was used as "local" at East Lansing, Merrill, and Reece, Michigan, and at Latty, Ohio. In one case U. S. 215 x 216 Commercial was significantly below Synthetic Check in sugar per acre, in two other tests the differences were large and in favor of Synthetic Check, but did not reach significance. In the fourth test the yields were about equal.

S.P. 4612-00 is a phase of U. S. 215 x 216 in which the male-sterile factor is utilized to enforce a greater degree of hybridization. If compared with 4-5-0, then on the basis of the 12 tests in which leafspot was absent, the variety produced 96.2 percent as much sugar per acre as Synthetic Check. It is doubtful if this difference is to be interpreted as significant, although significant differences were obtained in two tests.

[2]The numbers in parentheses refer to literature cited.

These results are in line with those reported previously and emphasize the challenge made to American sugar beet breeders. Synthetic Check is about representative of good European yield types of sugar beet. It shows a great range of adaptation and excellent crop returns when leafspot is not a factor. It appears that any superiority of American varieties in these tests is to be assigned to increased leafspot resistance rather than to innate productivity.

At the majority of the places at which tests were conducted *Cercospora* leafspot commonly occurs in epidemic form. The last three seasons have been characterized by the relative absence, or by the limited and late attack of *Cercospora* leafspot in the greater part of the tests. The general mean (table 4) shows that the gains from resistant varieties in the 5 tests with leafspot in 1947 more than offset the slightly lower average performance in the 12 tests without leafspot. By and large, then, no great cost is involved in using these leafspot-resistant varieties as insurance against crop loss from this disease.

A further consideration particularly applies to the districts that use the Scott-Urschel combine for harvesting the crop. The leafspot-resistant varieties give assurance that at harvest time a bouquet of leaves will be present to permit this type of machine to operate. Varieties whose tops are blighted and destroyed by leafspot cannot be harvested by a machine that operates on the principle of clasping the foliage between belts and elevating the plant to the topping disks.

The tetraploid U. S. 215 x 216, S.P. 4511-00, was made by mixing seed of U. S. 215 4n and U. S. 216 4n and then using the pooled seed to plant the seed field. The variety was of extreme interest to all viewing the tests. The large and heavy tops and the general vigor of growth attracted attention. In only a few tests, however, was the stand equivalent to that of the other varieties. Data as obtained for this variety conform to other experiences of the Division with tetraploids (1). The tetraploid showed that any increase in root yield was about offset by a lower sucrose percentage. The tendency of tetraploid seed to show a sprout count about equivalent to sheared seed has been reported (1). Exploration of advantage from establishing new varieties on the tetraploid level appears to be warranted.

Attention is called to the outstanding performance of a synthetic variety, S.P. 451034-0 (tables 1, 2, and 3). Under conditions of leafspot exposure, it was 15 percent better in gross sugar than Synthetic Check, achieving this because of its superior tonnage. In sucrose percentage it was equivalent to the check. Without leafspot, it yielded, on the average, as much as Synthetic Check and was not significantly lower in quality. In table 4, the good performance of the variety in 1947 is compared with similar good performance of its parent, S.P. 3-1834-00 in 1945. The last named variety was also increased as S.P. 4713-0 and seed is being supplied to cooperators for further increase. The variety, if and when formally released, will be designated as U. S. 226. It is proposed to utilize the variety as pollinator to produce U. S. 216 x 226. U. S. 226 by reason of the many

moderately leafspot-resistant varieties combined to produce it, has a broad genetic base and, therefore, wide adaptability. In U. S. 216 x 226, the male-sterile U. S. 216 will supply additional leafspot resistance, and the high degree of male sterility assures that the variety will be prevailing hybrid. Advantage from heterosis is expected (4).

In tables 1, 2, 3, and 4, data are given respecting S.P. 4610-00, a synthetic variety of much the same composition as U. S. 226. S.P. 4610-00 differs from S.P. 451832-00 tested in 1946 in that the latter was produced from identified $F_1$ roots planted together in the seed field, whereas the former was grown from seed obtained by pooling equal quantities of the 6 constituent inbreds. There was opportunity for sibbing in S.P. 4610-00, but any reduction in yield because of this was not noted. Since the two synthetic varieties have many inbreds in common, the similarity in performance is fully understandable. The results with S.P. 4610-00 are of value in supporting those obtained from S.P. 451034-0 (U. S. 226).

## Summary

Five leafspot-resistant varieties and one variety selected for high root yield from federal breeding investigations were compared in 17 tests with a check variety representative of European yield types of sugar beet. A variety currently being used locally in commercial sugar beet plantings was included in the tests at the various places. In those tests in which *Cercospora* leafspot was a factor, the 5 resistant varieties showed a superiority in sugar production of about 9 to 15 percent over the non-resistant varieties. In tests in which leafspot was a minor factor or absent, the varieties frequently did not show significant differences when compared with the checks. American bred varieties have been improved over European sorts in leafspot resistance and apparently derive their advantage from these factors rather than from a general increase in productivity. There are hopeful indications that highly productive varieties may be made leafspot resistant. These varieties would show significant advantage not only under conditions of leafspot exposure but under non-disease conditions as well. A variety, U. S. 216 x 226, giving such promise is being considered for release to the sugar beet industry.

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**Summary Table 1.**—Acre yields of gross sugar in agronomic evaluation tests of leafspot-resistant varieties: 1947.

| Location | Reported by | Varieties | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4511-00 | 451034-0 | 4610-00 | 4611-00 | 4612-00 | Neb. 30 | 4-5-0 | Local |
| **Tests in which Cercospora leafspot was a factor** | | | | | | | | | |
| Fort Collins, Colo. (Sprinkler) | G. W. Deming, J. A. Elder | 3831 | 4198 | 4033 | 3940 | 4010 | 3746 | 3914 | 4064 |
| Brush, Colo. | H. E. Brewbaker, H. L. Bush | 9320 | 9023 | 8904 | 8434 | 8694 | 7004 | 6978 | 8721 |
| Rocky Ford, Colo. | C. W. Doxtator | 4244 | 4175 | 4270 | 3922 | 3818 | 3633 | 3862 | 4151 |
| Mankato, Minn. | O. E. Reece, H. W. Bockstahler | 3708 | 4128 | 3884 | 4229 | 4197 | 3578 | 3828 | 3659 |
| Chatham, Ont. | H. L. Fletcher | 2893 | 3983 | 3964 | 4020 | 3628 | 3793 | 3596 | 3687 |
| Mean | | 4799 | 5101 | 5011 | 4909 | 4869 | 4351 | 4436 | 4856 |
| As percent of 4-5-0 | | 107.7 | 115.0 | 113.0 | 110.7 | 109.8 | 98.1 | 100.0 | 109.5 |
| **Tests in which Cercospora leafspot was absent or a negligible factor** | | | | | | | | | |
| Fort Collins, Colo. Agronomy Farm | G. W. Deming, J. P. Kintzley | 4316 | 4776 | 4754 | 4942 | 4528 | 5321 | 4809 | 4912 |
| Ault, Colo. | G. W. Deming, J. A. Elder | 5920 | 5992 | 6399 | 6047 | 6028 | 6450 | 6312 | 6476 |
| Longmont, Colo. | H. E. Brewbaker, H. L. Bush | 4593 | 4329 | 4324 | 4601 | 4428 | 4378 | 4699 | 4195 |
| Torrington, Wyo. | S. B. Nuckols, L. H. Paules | 4254 | 5160 | 5308 | 5200 | 4458 | 5464 | 5110 | 4868 |
| Sidney, Mont. | C. E. Cormany, D. F. Peterson | 3309 | 3710 | 3377 | 3442 | 2904 | 3611 | 3507 | 3052 |
| Scottsbluff, Neb. | S. B. Nuckols | 4344 | 4138 | 4002 | 4132 | 3614 | 4142 | 3840 | 3870 |
| Mason City, Ia. | C. W. Doxtator | 3423 | 3352 | 3314 | 3853 | 3409 | 3441 | 3335 | 3101 |
| Stewart, Minn. | O. E. Reece, H. W. Bockstahler | 3478 | 3809 | 3821 | 3832 | 3689 | 3883 | 3540 | 3503 |
| East Lansing, Mich. | J. G. Lill | 3750 | 4239 | 4373 | 4570 | 4236 | 4397 | 4302 | 3782 |
| Merrill, Mich. | J. G. Lill | 3064 | 3380 | 3295 | 3482 | 3394 | 3270 | 3156 | 2676 |
| Reece, Mich. | P. A. Reeve, Grant Nichol | 3576 | 3530 | 2982 | 3267 | 3317 | 3121 | 3689 | 3264 |
| Latty, Ohio | P. A. Reeve, Grant Nichol | 5922 | 6153 | 6218 | 5906 | 6117 | 5850 | 5793 | 5874 |
| Mean | | 4162 | 4381 | 4347 | 4440 | 4177 | 4444 | 4341 | 4131 |
| As percent of 4-5-0 | | 95.9 | 100.9 | 100.1 | 102.3 | 96.2 | 102.4 | 100.0 | 95.2 |
| General mean | | 4350 | 4593 | 4542 | 4578 | 4381 | 4417 | 4369 | 4344 |
| As percent of 4-5-0 | | 99.6 | 105.1 | 104.0 | 104.8 | 100.3 | 101.1 | 100.0 | 99.4 |

**Summary Table 2.**—Acre yields of roots in agronomic evaluation tests of leafspot-resistant varieties: 1947.

| Location | Reported by | Varieties | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4511-00 | 451034-0 | 4610-00 | 4611-00 | 4612-00 | Neb. 30 | 4-5-0 | Local |
| **Tests in which Cercospora leafspot was a factor** | | | | | | | | | |
| Fort Collins, Colo. (Sprinkler) | G. W. Deming, J. A. Elder | 13.71 | 15.29 | 14.45 | 14.24 | 13.87 | 13.63 | 14.27 | 14.60 |
| Brush, Colo. | H. E. Brewbaker, H. L. Bush | 29.53 | 28.25 | 27.18 | 26.24 | 26.14 | 22.04 | 22.70 | 26.54 |
| Rocky Ford, Colo. | C. W. Doxtator | 16.16 | 15.32 | 15.22 | 14.07 | 13.56 | 13.41 | 13.90 | 13.57 |
| Mankato, Minn. | O. E. Reece, H. W. Bockstahler | 11.95 | 12.60 | 11.73 | 12.86 | 12.41 | 10.92 | 11.49 | 10.84 |
| Chatham, Ont. | H. L. Fletcher | 10.25 | 13.57 | 13.62 | 13.54 | 12.02 | 12.43 | 12.15 | 12.45 |
| Mean | | 16.32 | 17.01 | 16.44 | 16.19 | 15.60 | 14.49 | 14.90 | 15.60 |
| Mean as percent 4-5-0 | | 109.5 | 114.2 | 110.3 | 108.7 | 104.7 | 97.2 | 100.0 | 104.7 |
| **Tests in which Cercospora leafspot was absent or a negligible factor** | | | | | | | | | |
| Fort Collins, Colo. Agronomy Farm | G. W. Deming, J. P. Kintzley | 16.44 | 17.41 | 17.04 | 17.52 | 16.06 | 18.23 | 17.55 | 17.55 |
| Ault, Colo. | G. W. Deming, J. A. Elder | 18.12 | 18.16 | 18.83 | 18.06 | 17.66 | 18.62 | 18.39 | 19.31 |
| Longmont, Colo. | H. E. Brewbaker, H. L. Bush | 15.87 | 14.98 | 15.27 | 16.11 | 15.31 | 14.73 | 16.27 | 14.71 |
| Torrington, Wyo. | S. B. Nuckols, L. H. Paules | 14.22 | 16.42 | 17.46 | 17.01 | 14.58 | 17.47 | 16.74 | 15.91 |
| Sidney, Mont. | C. E. Cormany, D. F. Peterson | 16.08 | 16.82 | 15.63 | 15.71 | 13.77 | 16.46 | 15.95 | 13.75 |
| Scottbluff, Neb. | S. B. Nuckols | 14.24 | 13.61 | 12.95 | 13.46 | 11.68 | 13.33 | 12.27 | 12.68 |
| Mason City, Ia. | C. W. Doxtator | 12.50 | 11.62 | 11.86 | 13.61 | 11.91 | 11.74 | 11.51 | 10.27 |
| Stewart, Minn. | O. E. Reece, H. W. Bockstahler | 11.21 | 12.12 | 12.13 | 12.30 | 12.03 | 12.38 | 11.30 | 11.29 |
| East Lansing, Mich. | J. G. Lill | 13.41 | 14.36 | 14.59 | 15.18 | 14.19 | 14.76 | 14.20 | 12.62 |
| Merrill, Mich. | J. G. Lill | 10.18 | 10.65 | 10.44 | 10.98 | 10.46 | 9.96 | 9.85 | 8.44 |
| Reece, Mich. | P. A. Reeve, Grant Nichol | 11.41 | 11.25 | 9.77 | 10.83 | 10.88 | 9.99 | 11.83 | 10.92 |
| Latty, Ohio | P. A. Reeve, Grant Nichol | 19.09 | 19.06 | 19.03 | 18.32 | 18.49 | 18.24 | 17.92 | 17.70 |
| Mean | | 14.40 | 14.70 | 14.58 | 14.92 | 13.92 | 14.66 | 14.48 | 13.76 |
| As percent of 4-5-0 | | 99.4 | 101.5 | 100.7 | 103.0 | 96.1 | 101.2 | 100.0 | 95.0 |
| General mean | | 14.96 | 15.38 | 15.13 | 15.30 | 14.41 | 14.61 | 14.61 | 14.30 |
| As percent of 4-5-0 | | 102.4 | 105.3 | 103.6 | 104.7 | 98.6 | 100.0 | 100.0 | 97.9 |

**Summary Table 3.**—Sucrose percentages in agronomic evaluation tests of leafspot-resistant varieties: 1947.

| Location | Reported by | Varieties | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4511-00 | 451034-0 | 4610-00 | 4611-00 | 4612-00 | Neb. 30 | 4-5-0 | Local |
| **Tests in which Cercospora leafspot was a factor** | | | | | | | | | |
| Fort Collins, Colo. (Sprinkler) | G. W. Deming, J. A. Elder | 13.98 | 13.68 | 13.96 | 13.84 | 14.44 | 13.72 | 13.71 | 13.90 |
| Brush, Colo. | H. E. Brewbaker, H. L. Bush | 15.78 | 15.97 | 16.38 | 16.07 | 16.63 | 15.89 | 15.37 | 16.43 |
| Rocky Ford, Colo. | C. W. Doxtator | 13.15 | 13.59 | 13.99 | 13.90 | 14.16 | 13.46 | 13.90 | 15.28 |
| Mankato, Minn. | O. E. Reece, H. W. Bockstahler | 15.51 | 16.39 | 16.55 | 16.47 | 16.89 | 16.37 | 16.61 | 16.86 |
| Chatham, Ont. | H. L. Fletcher | 14.09 | 14.66 | 14.57 | 14.83 | 15.08 | 15.20 | 14.82 | 14.81 |
| Mean | | 14.50 | 14.86 | 15.09 | 15.02 | 15.44 | 14.93 | 14.88 | 15.46 |
| As percent of 4-5-0 | | 97.4 | 99.9 | 101.4 | 100.9 | 103.8 | 100.3 | 100.0 | 103.9 |
| **Tests in which Cercospora leafspot was absent or a negligible factor** | | | | | | | | | |
| Fort Collins, Colo. Agronomy Farm | G. W. Deming, J. P. Kintzley | 13.11 | 13.72 | 13.92 | 14.08 | 14.07 | 14.59 | 13.71 | 13.99 |
| Ault, Colo. | G. W. Deming, J. A. Elder | 16.34 | 16.47 | 17.00 | 16.71 | 17.07 | 17.33 | 17.15 | 16.76 |
| Longmont, Colo. | H. E. Brewbaker, H. L. Bush | 14.46 | 14.46 | 14.14 | 14.23 | 14.50 | 14.89 | 14.46 | 14.29 |
| Torrington, Wyo. | S. B. Nuckols, L. H. Paules | 14.98 | 14.94 | 15.25 | 15.31 | 15.31 | 15.60 | 15.24 | 15.26 |
| Sidney, Mont. | C. E. Cormany, D. F. Peterson | 10.31 | 11.00 | 10.81 | 10.96 | 10.56 | 10.99 | 10.98 | 11.14 |
| Scottsbluff, Neb. | S. B. Nuckols | 15.30 | 15.10 | 15.50 | 15.30 | 15.40 | 15.50 | 15.60 | 15.20 |
| Mason City, Ia. | C. W. Doxtator | 13.70 | 14.40 | 14.00 | 14.20 | 14.40 | 14.70 | 14.60 | 15.10 |
| Stewart, Minn. | O. E. Reece, H. W. Bockstahler | 15.61 | 15.71 | 15.76 | 15.59 | 15.36 | 15.69 | 15.69 | 15.53 |
| East Lansing, Mich. | J. G. Lill | 14.06 | 14.72 | 15.04 | 15.08 | 14.92 | 14.92 | 15.21 | 15.04 |
| Merrill, Mich. | J. G. Lill | 15.06 | 15.90 | 15.72 | 15.82 | 16.26 | 16.42 | 16.01 | 15.86 |
| Reece, Mich. | P. A. Reeve, Grant Nichol | 15.70 | 15.65 | 15.18 | 15.00 | 15.34 | 15.62 | 15.51 | 14.94 |
| Latty, Ohio | P. A. Reeve, Grant Nichol | 15.56 | 16.14 | 16.34 | 16.13 | 16.59 | 16.01 | 16.19 | 16.81 |
| Mean | | 14.52 | 14.85 | 14.89 | 14.87 | 14.98 | 15.19 | 15.03 | 14.99 |
| As percent of 4-5-0 | | 96.6 | 98.8 | 99.1 | 98.9 | 99.7 | 101.1 | 100.0 | 99.7 |
| General mean | | 14.51 | 14.85 | 14.95 | 14.91 | 15.12 | 15.11 | 14.99 | 15.13 |
| As percent of 4-5-0 | | 96.8 | 99.1 | 99.7 | 99.5 | 100.9 | 100.8 | 100.0 | 100.9 |

**Summary Table 4.**—Comparisons of leafspot-resistant varieties with Synthetic Check, 4-5-0, together with applicable data from tests of previous years. (Percentages are based upon performance of 4-5-0 in year indicated).

| Variety | | Year | No. of tests averaged | Acre-yield | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Gross sugar | | Roots | | Sucrose | |
| S.P. Number | Description | | | Average | As percent of 4-5-0 | Average | As percent of 4-5-0 | Average | As percent of 4-5-0 |
| 4-5-0 | Synthetic Check | 1945 | 13 | 3793 | 100. | 12.36 | 100. | 15.31 | 100.0 |
| 4-5-0 | (Seed of 9 European varieties | 1946 | 16 | 4714 | 100. | 14.28 | 100. | 16.89 | 100.0 |
| 4-5-0 | mixed and used as seed stock) | 1947 | 17 | 4369 | 100. | 14.61 | 100. | 14.99 | 100.0 |
| 2-1-00 | U.S. 215 x 216/1 | 1945 | 13 | 3659 | 96.5 | 11.72 | 94.8 | 15.50 | 101.2 |
| 4510-00 | U.S. 215 x 216/2 | 1946 | 16 | 4581 | 97.2 | 14.05 | 98.4 | 16.72 | 99.0 |
| 4-7-00 | U.S. 215 x 216/3 | 1945 | 13 | 3596 | 94.8 | 10.99 | 89.2 | 16.21 | 105.1 |
| 4-7-00 | U.S. 215 x 216/3 | 1946 | 16 | 4273 | 90.6 | 12.50 | 87.5 | 17.42 | 103.1 |
| 4511-00 | U.S. 215 x 216 4n | 1947 | 17 | 4350 | 99.5 | 14.96 | 102.4 | 14.51 | 96.8 |
| 4612-00 | U.S. 215 Imp. x U.S. 216 M.S. | 1947 | 17 | 4381 | 100.3 | 14.41 | 98.6 | 15.12 | 100.9 |
| 3-1834-00 | Synthetic variety | 1945 | 13 | 3975 | 104.8 | 12.99 | 105.1 | 15.27 | 99.7 |
| 451034-0 | Direct increase of above | 1947 | 17 | 4593 | 105.1 | 15.38 | 105.3 | 14.85 | 99.1 |
| 451832-00 | Synthetic variety | 1946 | 16 | 4918 | 104.3 | 15.13 | 106.0 | 16.43 | 97.3 |
| 4610-00 | Synthetic variety | 1947 | 17 | 4542 | 104.0 | 15.13 | 103.6 | 14.95 | 99.7 |
| Local[1] | From beet sugar companies | 1945 | 13 | 3789 | 99.9 | 12.36 | 100.8 | 15.31 | 99.2 |
| Local | From beet sugar companies | 1946 | 16 | 4790 | 101.6 | 14.33 | 100.4 | 17.08 | 101.1 |
| Local | From beet sugar companies | 1947 | 17 | 4344 | 99.4 | 14.30 | 97.9 | 15.13 | 100.9 |

[1]Supplied by beet sugar companies. In 1947, U.S. 215 x 216 Commercial was used as "local" in 6 tests.

# A Promising Sugar Beet Hybrid of the Milpitas Wild Type X Commercial

H. W. Dahlberg[1] and H. E. Brewbaker[2]

In the area around San Jose and Milpitas, California, there is a large population of sugar beets which grow wild along the main highway and the Southern Pacific tracks. They have also been observed growing in the industrial areas of San Jose and in lawns in that city. These beets are very prolific seed producers, and it is indicated that the same root not only produces seed the first year but also continues to grow and produce seed for several seasons in this area.

The senior author first observed these beets in the fall of 1937, as they were growing along the paved highway south of Milpitas. At that time 1 or 2 pounds of seed were gathered from 50 to 100 individual beets growing close to the highway. He was struck with their similarity to Beta Maritima individuals which he had studied on the coasts of France and England in 1934. Many of the seedstalks carry the same red-veined coloring as Beta Maritima, and the roots are tough and woody with many multiple crowns. These characters are quite common with Beta Maritima and as you will notice from the slides which will be shown, the beets also have the large side roots which are so evident in the wild types. It is our opinion that these Milpitas beets carry a high percentage of Beta Maritima blood and there can be little question that their origin goes back to the coasts of the Mediterranean Sea.

It is an interesting speculation as to when these wild types first reached this section of California. There are two distinct possibilities, either of which offers a satisfactory explanation.

1. According to Dan Gutleben, who has made a study of the early history of the beet sugar industry, sugar beets for commercial use were first grown in the south San Francisco area about 1856. The San Jose Pioneer Beet Sugar Manufacturing Company was organized in the spring of that year, and presumably beets were grown between south San Francisco and San Jose for one or more years. E. F. Dyer began building the Alvarado factory in 1869 and raised beets experimentally before that. Beet seed imported from Europe in these early years was not all sugar beet seed, and carried mangold and possibly other strains as well. The present Milpitas strain may represent the survivor of some of these types of beets first planted in California about 90 years ago.

2. The other possibility is that when the Franciscan Fathers built the Santa Clara and other missions about 100 years earlier, 1770 to 1780, they may have introduced various types of beets for use as vegetables or

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salad greens. Our history books tell us that the Franciscans introduced into California many agricultural seeds, fruits and shrubs from Southern Europe, so they almost surely introduced beets of various types, including Beta Maritima. With the strong tendency to annualism in Beta Maritima, it would be a simple matter for these beets to become wild and grow like weeds year after year in the mild climate of California.

Our theory in using this wild material for breeding purposes was that the individuals which had survived drouth, diseases and other hazards for many generations might carry valuable genes for disease resistance, as well as other desirable characters. This material was found to possess considerable resistance to *Cercospora* leafspot when grown under conditions of heavy leafspot incidence on susceptible strains.

The wild Milpitas strain is a complete annual when grown in Colorado, and even after five generations of selection the present Milpitas-Great Western hybrid shows about 3 percent bolters. The original Milpitas strain segregates for about 25 percent red or pink roots and 75 percent white roots. In addition to severe selection against bolting, we have selected for desirable root type, white roots, and leafspot resistance. Our general procedure, which involved crossing, backcrossing, and selection, is given in detail as follows:

Parents: (1937-38) LSR-GW Gr. 3718 and B.Mar. "Milpitas."

$F_1$, 1938—Segregated for bolting and color of root.

Backcross to Gr. 3719 in 1940—Segregated for bolting and color of root. Only white roots selected.

3rd gen., 1942—All white roots.

4th gen., 1944—Near-commercial in type of root.

5th gen., 1946—B332. Roots commercial in type.

The degree of improvement in reduced annualism secured in 5 years of selection is shown in table 1.

**Table 1.—Demonstration plots, 1947.**

| Lot or generation | Leafspot[1] rating | Bolters (percent) |
|---|---|---|
| B. mar. Milpitas | 3 | 100.0 |
| $F_1$ gen. | 3 | 92.1 |
| Backcross to Gr. 3719 | 2 | 25.4 |
| 3rd gen. | 2 | 7.8 |
| 4th gen. | 2 | 4.8 |
| 5th gen. | 1 | 3.0 |

[1]Scale of 1 = very resistant to 10 = very susceptible.

In the fall of 1937 a greenhouse planting of the Milpitas strain was made and allowed to pollinate in close proximity to the leafspot-resistant G.W. strain 3718. Seed harvested from both parents was planted to the field in May 1938 at both Sterling and Longmont. The reciprocal sides of the cross showed a leafspot reading of 1 for both as compared with readings of 6 to 7 for the standard commercial GW18.

In 1939, 11 white and 13 red roots from the cross B. mar. Milpitas x Gr. 3718 and reciprocal were backcrossed to 16 roots of a closely related LSR strain Gr. 3719.

In 1940, a selection was made for leafspot resistance and non-bolting. This type of selection was repeated again in 1942 and 1944. Seed was produced from the last selection of 103 roots in 1945, and this represents the present hybrid strain known as B332. Variety-test results are presented for 1946 in table 2 and for 1947 in table 3. Varieties GW85 and GW59 used for comparison are "LSR" and "Yield" commercials.

Table 2.—Variety test, 1946.

| Lot | Roots (tons) | Sugar (percent) | Sugar (pounds) | Leafspot Rating |
|---|---|---|---|---|
| **Longmont:** | | | | |
| B332 | 20.28 | 13.2 | 5354 | -- |
| GW85 | 21.27 | 13.7 | 5828 | -- |
| **Morgan Co.:** | | | | |
| B332 | 25.53 | 13.53 | 6908 | 1.5 |
| GW85 | 20.82 | 13.42 | 5598 | 4.7 |
| LSD 5 percent pt. | 2.77 | .78 | 813 | -- |

Table 3.—Variety test, 1947.

| Lot | Tons beets per acre | | | Percent sugar | | | Lbs. sugar per acre | | | Leaf-spot Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lmt. | M. Co. | Mean | Lmt. | M. Co. | Mean | Lmt. | M. Co. | Mean | M. Co. |
| B332 | 17.17 | 28.55 | 22.86 | 14.77 | 15.26 | 15.02 | 5079 | 8713 | 6896 | 1.2 |
| GW59 | 16.68 | 27.70 | 22.19 | 15.70 | 15.23 | 15.47 | 5157 | 8437 | 6797 | 4.7 |
| GW85 | 16.20 | 24.92 | 20.56 | 14.92 | 15.66 | 15.29 | 4795 | 7805 | 6300 | 3.2 |
| LSD 5 percent pt. | 1.51 | 2.76 | 1.57 | .55 | .73 | .46 | 497 | 853 | 494 | |

With the exception of having about 3 percent bolters, B332 is fully commercial in sugar production per acre and constitutes one of our outstanding leafspot-resistant strains. In 1947, when our commercial LSR variety GW85 had an LSR reading of 3.2 and completely susceptible varieties up to 6 or 7, B332 had an LSR reading of 1.2 in the Morgan County test. As an average of both tests it is equal to GW59 and superior to GW85 in production of total sugar per acre.

In the spring of 1947 a demonstration series of 6 plots, consisting of the original wild Milpitas seed and each generation of the cross with Grs 3718 and 3719, was planted at Fort Morgan. This series of plots provided a very striking demonstration of the reduction in bolting (table 1), also improvement in root type and commercial possibilities. In this planting the Milpitas wild strain showed some of the largest seedballs we have ever observed. We were able to count as many as 11 florets per seedball.

The development of the hybrid strain B332 has been a very interesting experience, and emphasizes the fact that breeding material may look very unpromising and still be very valuable, if one has the patience to spend

the time required for the elimination of many undesirable characters. Work already in progress is designed to eliminate the remaining 3 percent of bolters by planting seed under winter conditions in February and selecting only the non-bolters for seed production.

The annualism in this hybrid variety could have been eliminated more rapidly by selection from plantings made in the very early spring. However, we believe the procedure we used was safer in that if we had eliminated all the annuals in 1 or 2 years of selection we might at the same time have lost other valuable characters.

In this study, wild beets from Milpitas, California, were shown to possess decided resistance to *Cercospora* and to be a valuable source of breeding material. A hybrid resulting from a cross of these wild beets with a Great Western Strain now shows good production of sugar per acre along with outstanding resistance to leafspot and other desirable characters.

# New Sugar Beet Strains from U.S. 22 With Higher Curly-Top Resistance

ALBERT M. MURPHY, F. V. OWEN AND G. K. RYSER[1]

CURLY-TOP-RESISTANT varieties of sugar beets are now grown exclusively in areas of the western United States where the curly-top disease is a factor in sugar beet production. Curly-top-resistant varieties have been in use only 13 years and there has been a rapid succession of varieties. U.S. 1 was the first variety released (1)[2] and was soon replaced by other varieties (2). These varieties were in turn replaced by U.S. 22 and a further selection has resulted in strains with still a higher degree of resistance. The second release of U.S. 22 is designated U.S. 22/2 and now has reached the dominant position for the major part of the curly-top area.

## Source of Material and Method

When the variety U. S. 22/2 was grown under a very drastic curly-top exposure it proved to be an excellent source from which to select individual beets with superior curly-top resistance. The production of such heavy curly-top exposures in the beet breeding field has been discussed elsewhere (3). As a result of selection from U.S. 22/2, strains have been obtained that are considerably higher in curly-top resistance. One of these selections, designated as U.S. 22/3, is now being propagated for commercial use. A selection was made from U. S. 22/3 and designated S.L. 61. Another selection, designated S.L. 62, was obtained in a comparable way from U.S. 22/3. Both selections were made on the basis of disease resistance alone without any sugar determinations.

## Results

In a May 20, 1947, test at Jerome, Idaho, where curly top was so severe that it completely destroyed such varieties as R. & G. Old Type, U.S. 15 and U.S. 33, the following results were obtained:

| Variety | Tons per acre | Average C. T. Grade |
|---|---|---|
| Original U.S. 22 (SL 922) | 6.47 | 3.05 |
| 2nd Rel. U.S. 22/2 (SL 222) | 10.78 | 2.85 |
| 3rd Rel. U.S. 22/3 (SL 32) | 15.85 | 2.00 |
| S.L. 61 | 16.51 | 1.80 |
| S.L. 62 | 16.29 | 1.65 |

A summary of agronomic evaluation tests of the above varieties shows that there has been a tendency for reduced sucrose percentage in the case of U.S. 22/3 and S.L. 61, but that the reduction was usually less than 0.2

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[2]The numbers in parentheses refer to literature cited.

percent and was too small to measure by statistical methods in well-replicated tests. S.L. 62 showed little superiority over S.L. 61 in curly-top resistance in the May planting but in a still later planting made June 25 where the curly-top exposure was more drastic, S.L. 62 showed greater curly-top resistance than any of the above-mentioned varieties. A few individual beets in S.L. 62 showed remarkable resistance and a further selection of these superior beets was made in 1947. S.L. 62 has not as yet been adequately tested for sugar content.

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# A New Sugar Beet Variety, U.S. 56, for Fall and Winter Plantings in California

CHARLES PRICE, F. V. OWEN AND EUBANKS CARSNER[1]

NEED FOR VARIETIES low in bolting tendency for winter planting in California has long been recognized. When the first curly-top-resistant varieties were released they were found to bolt much more readily than some of the better European varieties and were not suitable for fall or winter planting. These facts, together with the need for varieties resistant to downy mildew, caused the addition of new objectives to the project of breeding sugar beets for curly-top resistance. Later, as sugar beet growing expanded into curly-top areas where fall and winter plantings were desirable, the demand for high curly-top resistance combined with resistance to bolting and to downy mildew grew stronger.

## Range of Planting Dates

The relatively mild climate of California permits a wide range of planting dates with sugar beets grown for sugar. Imperial Valley fields are planted early in October. This date is only 6 to 8 weeks later than sugar beets are planted in the Salt River Valley of Arizona for seed growing by the method of overwintering in the field. In view of the fact that the winters in this nearby seed-growing area are not much colder than are those of Imperial Valley the need for a non-bolting variety for sugar production in the latter area becomes obvious. Winter planting is advantageous for a large portion of the San Joaquin Valley area and parts of the coastal districts. Non-bolting varieties must be used for these plantings. Plantings can be made in some of the districts as late as May and June but in these plantings bolting is not an important problem.

## Breeding for Resistance to Bolting and Downy Mildew

An agronomic evaluation test including eleven varieties was planted near Salinas, California, December 6, 1934. Downy mildew was unusually abundant at Salinas and elsewhere in California in the spring of 1935. Indications of resistance to downy mildew and marked differences in bolting tendency were revealed by the Salinas test. The results as to bolting and downy-mildew infection with six of the varieties are given in table 1. U.S. 1 was the first curly-top-resistant variety released. U.S. 33 and U.S. 34 soon superceded it. The other three varieties were lower in bolting tendency. They included a variety, bred by Dr. G. H. Coons and his associates, subsequently designated U.S. 15. The other two varieties were R. & G. Old Type and S.L. 4913, a variety of high curly-top resistance.

[1]Agronomist, Senior Geneticist, and Principal Pathologist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

Further study of U.S. 15 led to its release for extensive use for winter plantings in California coastal areas. This variety, in addition to its resistance to bolting and moderate resistance to downy mildew, is also moderately resistant to curly top, closely comparable to U.S. 1 in this respect. Due to this characteristic and its resistance to bolting, U.S. 15 soon replaced Old Type for fall planting in Imperial Valley where curly top has occasionally caused large losses.

**Table 1.—Bolting and downy-mildew infection results in test planted at Salinas, California, December 6, 1934.**

| Variety | Bolting 6-25-35 | Downy mildew 4-25-35 |
|---|---|---|
| | percent | percent |
| U.S. 1 | 90.8 | 25.4 |
| U.S. 33 | 40.4 | 26.5 |
| U.S. 34 | 62.6 | 30.8 |
| U.S. 15 | 0.5 | 14.0 |
| S.L. 4913 | 19.4 | 9.5 |
| Old Type | 7.8 | 17.5 |

Impetus to breeding for resistance to bolting and downy mildew was another outcome of the test at Salinas in 1934 and 1935. Dr. L. D. Leach of the Division of Plant Pathology, University of California, visited this plot in the spring of 1935 and observed the evidence of varietal differences in resistance and susceptibility to downy mildew. This led to a temporary cooperative breeding arrangement with the University with F. G. Larmer representing the Division of Sugar Plant Investigations. Leach's (1)[2] work resulted in the development of a strain of U.S. 33 improved as to downy-mildew resistance and equal to the original U.S. 33 in bolting tendency. The commercial U.S. 33 had been deteriorated in bolting tendency by reproduction under mild-climate conditions. The University later turned over Leach's selected material to the Division of Sugar Plant Investigations. After the improved U.S. 33 had been extensively evaluated it was released for commercial use.

Larmer's work on breeding resulted in the production of a strain of U.S. 15 improved in downy-mildew resistance and equal to the original variety in bolting tendency. He also made the primary selections which resulted in the development of the variety U.S. 56.

## Origin of U.S. 56

A variety planting for a downy-mildew test was made by F. G. Larmer near Spreckels, California, in mid-January, 1938. Three hundred and twenty-one mother beets were selected the following summer for resistance to downy mildew and bolting from six of the strains included in the test. These six strains were developed in the curly-top resistance breeding work at Salt Lake City, Utah. One of these, later designated U.S. 23, was the progeny of selections from S.L. 4913. One was the progeny of non-bolting selections from U.S. 12 and U.S. 33. A third one was the progeny of non-bolting selections from U.S. 33 and two other numbers. The other

[2]The numbers in parentheses refer to literature cited.

three strains arose from clones which had been selected for non-bolting and curly-top resistance from U.S. 12, A-600, and several other varieties.

The selected mother beets were all planted in one group at Medford, Oregon, in October, 1938. The seed obtained from them in the summer of 1939 was labeled S.L. 948. Some of this seed was planted by Larmer at Salinas, California, September 2, 1939. Those that bolted (probably 95 percent) in that planting were removed. Finally, 107 mother beets were selected and planted at Ashland, Oregon. Of these, 58 survived and produced seed which was given the number S.L. 1-41.

A planting of S.L. 1-41 was made at King City, California, February 12, 1943, by the senior author. A refractometer and polariscope selection yielded 200 mother beets and of these 35 plants were saved. These were reproduced at Riverside, California, and the seed was assigned the number S. L. 356. Increases of this number in Oregon and Utah gave rise to the variety U.S. 56.

### Comparison of U.S. 15 and U.S. 56

U.S. 15 replaced non-bolting European varieties for all fall and winter plantings in California. Commercial use of U.S. 15 was started in 1939. Critical evaluation in variety tests and subsequent extensive commercial use afforded enough information about the variety to make it useful as a standard for comparison. In bolting tendency it is better than R. & G. Old Type. It was originally moderately resistant to downy mildew and by reselection has been slightly improved in this respect. It has about the same degree of curly-top resistance as U.S. 1. The variety tends to be a sugar type and gives its best performance on soils of high fertility.

U.S. 56 has proved equal to or slightly better than U.S. 15 in downy-mildew resistance and in resistance to bolting. The bolting counts on May 26, 1947, in a test planted at Riverside, California, on August 21, 1946, gave the following bolting percentages: U.S. 56, 31; U.S. 15, 54; Old Type, 74. U.S. 56 is about equal to U.S. 15 in yield and sugar percentage when curly top is not a factor.

The most important characteristic of U.S. 56 in which it is superior to U.S. 15 is in curly-top resistance. A simple test in Imperial Valley, California, in the season of 1945-1946 revealed a distinct difference between the two varieties under the moderate curly-top exposure there that season. U.S. 56 exceeded U.S. 15 in yield by nearly 4 tons per acre. A test in 1946 in the San Joaquin Valley near Bakersfield, California, had a severe curly-top exposure. Due to an infestation of *Sclerotium rolfsii* the plot was not harvested but observations revealed that U.S. 56 seemed nearly as resistant to curly top as the original or first release of U.S. 22.

### Tests of U.S. 56 in 1947

Many comparative tests including U.S. 15, U.S. 56 and other varieties were conducted in California in 1947. The results where curly top

was not a factor supported previous evidence that U.S. 15 and U.S. 56 are close competitors in the absence of curly-top damage. The results of some of the tests under curly-top exposure in the San Joaquin Valley will be adequate to indicate the performance of U.S. 56 under such conditions.

A grower-test planting, including U.S. 15 and U.S. 56, was planted on the ranch of John J. and Ike J. Peters near Cawelo in Kern County, California, on January 11, 1947, and harvested early in August. The yield of U.S. 15 was 22 tons per acre, while that of U.S. 56 was 34.6 tons per acre. The difference here in the performance of these varieties was due in part but not entirely to difference in curly-top resistance. There was more root rot due to Rhizoctonia evident in U.S. 15 at the end of the season. Lower vigor and less favorable color in U.S. 15 were noted in the spring before curly-top injury became conspicuous but the cause of this difference was not determined.

A grower-test planting with U.S. 15 and U.S. 56 planted in mid-December and mid-January near Five Points in western Fresno County, California, included strips of each variety. The results of this test, given in table 2, show that under the curly-top exposure there U.S. 56 yielded 8.1 tons per acre more than U.S. 15 in the December planting and 12 tons per acre more in the January planting. Due to frost injury the stand was not as good in the December planting as it was in the January planting. The reduction in yield with U. S. 15 was caused mainly by curly top even though the whole field was sprayed with DDT late in April for beet leafhopper and curly-top control. On May 6, U.S. 15 had 22 percent obvious curly top while U.S. 56 had only 1 percent A view of the December-planted strips is shown in figure 1.

**Table 2.**—**Variety test on Frank C. Diener ranch near Five Points, Fresno County, California. Harvested July 22, 1947.**[1]

| Variety | Tons per Acre | | Sucrose |
|---|---|---|---|
| | Gross Sugar | Beets | |
| **Mid-December, 1946, Planting** | | | |
| U.S. 56[2] | 2.872 | 17.5 | 16.41 |
| U.S. 15[3] | 1.660 | 9.4 | 17.66 |
| **Mid-January, 1947, Planting** | | | |
| U.S. 56[4] | 3.619 | 21.3 | 16.99 |
| U.S. 15[5] | 1.622 | 9.3 | 17.44 |

[1]Data through courtesy of R. J. Tingley, Holly Sugar Corporation.
[2]Average of 2.84 acres.
[3]Average of 17.6 acres.
[4]Average of 2.84 acres.
[5]Average of 5.25 acres.

A comparison of U.S. 15 and U.S. 56 was made in a variety test at the United States Cotton Field Station at Shafter, California. Plantings were made October 11 and November 26, 1946. There was no spraying or dusting for beet leafhopper control. The harvest results are summarized in table 3. U.S. 56 gave 7.9 tons per acre more than U.S. 15 in the October planting and 11.7 tons per acre more in the November planting.

Outstanding results were obtained from another variety test planted at the United States Cotton Field Station, Shafter, California, on March

**Table 3.—Variety test at United States Cotton Field Station, Shafter, California. Harvested July 30, 1947.**

| Variety | Tons per Acre | | Percent sucrose | Coeff. of app. purity | Beets per 100′ of row |
|---|---|---|---|---|---|
| | Gross sugar | Beets | | | |
| **October 11, 1946, Planting** | | | | | |
| U.S. 56 | 4.758 | 33.25 | 14.44 | 88.14 | 105 |
| U.S. 15 | 3.894 | 26.39 | 14.75 | 88.62 | 106 |
| Sig. Diff. (Odds 19:1) | .2996 | 1.543 | .433 | N. S. | |
| **November 26, 1946, Planting** | | | | | |
| U.S. 56 | 4.961 | 38.45 | 12.90 | 87.36 | 108 |
| U.S. 15 | 3.508 | 26.83 | 13.09 | 87.36 | 110 |
| Sig. Diff. (Odds 19:1) | .2938 | 1.791 | .366 | N. S. | |

18, 1947, and not harvested until November 4-6, 1947. The plots were heavily infested with beet leafhoppers while the plants were small and there was an abundant supply of curly-top virus in adjacent plots of beets planted in the fall. The appearance of the plot in early June is shown in figure 2. A strip of the German variety, Old Type, in this test was so severely injured that no marketable beets were obtained from it at harvest. A strip of U.S. 15 gave a total yield, including non-marketable beets, of only 6.18 tons per acre. Other varieties replicated ten times gave average yields of marketable beets, tons per acre, as follows: U.S. 56, 34.47; original U.S. 22, 41.64; second release of U.S. 22, 46.99; third release of U.S. 22, 53.22. These results support other evidence to the effect that in plantings

Figure 1.—Grower-test planting on Frank C. Diener ranch near Five Points, Fresno County, California. Strip of U.S. 15 at left and of U.S. 56 at right. Seedstalks in background at right are in strip of U.S. 22. Planted mid-December, 1946. Photographed July 22, 1947.

where severe curly-top exposure is a possibility and where downy mildew and bolting will not be important factors varieties even higher in curly-top resistance than U.S. 56 are to be preferred.

## Summary

The variety U.S. 56 represents an indirect synthetic mixture of curly-top-resistant material derived from several sources. Three of the sources were progenies originating from vegetative clones previously selected for non-bolting as well as for curly-top resistance. The other sources were: (1) a curly-top-resistant variety having moderate downy-mildew resistance; (2) the progeny of non-bolting selections from U.S. 12 and U.S. 33; (3) the progeny of non-bolting selections from U.S. 33 and two other numbers.

U.S. 56 is decidedly superior to U.S. 15 in curly-top resistance. It is about equal to that variety in downy-mildew resistance and slightly better than U.S. 15 in resistance to bolting.

Under moderate to very severe curly-top exposures U.S. 56 has excelled U.S. 15 by wide margins in tonnage of beets and sugar per acre. Under conditions where curly-top was not a factor, U.S. 56 and U.S. 15 have been practically equal in performance. U.S. 56 is the best variety now available for fall and winter planting in interior areas of California where curly top may be a factor and in coastal districts where curly top and downy mildew may be factors.

Figure 2.—Variety test at U.S. Cotton Field Station, Shafter, California. Replicated plots at left. Two-row strips beginning at center and reading left to right: Old Type, U.S. 15, U.S. 56, U.S. 22, and then 4 rows of U.S. 22/2. Planted March 18, 1947. Photographed June 9, 1947.

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# Breeding Sugar Beets With Root Conformation Adapted to Machine Harvest[1]

G. W. Deming[2]

THE VARIETIES of sugar beet as now grown are all characterized by having more or less elongated, obconical roots. Although soil and growing conditions may modify root shape to some extent, long parsnip-shaped roots that gradually taper to a point are the rule. A much shorter and more or less globe or top-shaped root would be easier to loosen and lift from the ground and could, therefore, be handled more efficiently by sugar beet harvesting machines. In addition, losses by breakage of the roots in the harvest operation and in the subsequent delivery of the beets to the sugar factory would be reduced.

Late in the 1947 harvest season hybrid beets with predominantly short, thick roots were given a trial run at Fort Collins, Colorado, with a harvester which tops the beets after lifting. Those who witnessed this trial were very favorably impressed by the efficiency of the harvester in handling these globose rooted sugar beets. Very few individuals were lost from the machine and there was practically no root breakage.

It is known that Achard's original "Runkelrüben," from which the sugar beet has been derived, consisted of an exceedingly variable mixture of types. The sucrose percentage of the roots, in comparison with modern sugar beets, varied from very low to mediocre. Achard noted three distinct root shapes in these beets: round, nearly apple-shaped roots; short, large crowned, radish- or pear-shaped roots; and long, spindle-shaped beets, gradually coming to a point. The general growth habit of the last class resembled that of our modern, long mangel-wurzels. However, it was in these long rooted types that Achard found the individuals that he believed contained the most extractable sugar. The White Silesian variety was obtained from Achard's selections.

Breeding of sugar beets has served to concentrate certain factors that were present in the White Silesian beet and has produced a beet of long, obconic shape, white in color and with a sugar content probably double that of the best individuals of the progenitor. Since high sugar content has always been the first concern of sugar beet breeders we might assume that the white color and conical shape of our sugar beets are characters that are linked with high sucrose content. Data from a selection project at

[1]Science Series paper No. 260, Colorado Agricultural Experiment Station. Investigations of the Division of Sugar Plant Investigations at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado Agricultural Experiment Station. Certain phases of these investigations are also cooperative with the Larimer County, Colo., Board of County Commissioners.

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Fort Collins indicate that the factors responsible for white color and high sugar content are linked, at least to some degree. For example, continued selections in a sugar beet x red garden beet hybrid were made on the basis of sucrose percentages and root weights, all other characters being disregarded. The $F_2$ of this hybrid contained approximately 75 percent of red roots. In the fourth generation of the line selected on the basis of high sugars and high root weights approximately 40 percent of the roots were red. In the sister line selected for low sugars and high root weights, approximately 90 percent of the fourth generation were red beets. Thus, it appears that there is a sound genetic reason for the white color of sugar beets.

The writer has observed little, if any, evidence that there is a similar linkage of the factors determining cone shape of root and high sucrose percentage. Hence, there is probably no genetic bar to the development of a short, more or less globe- or top-shaped beet that could be more efficiently handled by machinery than the present type of sugar beet root. The problem thus becomes one of finding suitable parent material from which the plant breeder may produce a sugar beet of the desired conformation. There are two main sources from which such parent material may be drawn. The more obvious of these sources is among the non-sugar varieties of beets, such as the more or less flattened or globe-shaped varieties of the red garden beet. The other source is from our present varieties of sugar beets. The factors for high sugar content, undoubtedly, must come from the latter source and it is probable that factors for short-root shape may also be found in our sugar beet varieties.

Since the trial run of the harvester at Fort Collins was made on a variety originating from a sugar x red garden beet hybrid, the possibilities of this cross will be considered first. This variety was the $F_4$ of a cross of U.S. 200 x 216 and a more or less globe-shaped red garden beet (variety unknown). White roots with better-than-average sugar content were selected from the $F_2$ of this hybrid. From the progeny, roots were again selected in the same manner to produce the seed from which the current ($F_4$) was grown. In spite of the fact that no attention was paid to root shape in these two selections, the $F_4$ of this hybrid had roots that were predominantly more or less globe- to top-shaped. There were also present in this crop a few beets that were either of long, obconic shape like the sugar beet or of typical globe shape like the red garden beet.

In 1947, at the experimental field on the Larimer County, Colorado, Hospital Farm, the buffer areas, in which are planted the overhead sprinkler lines, were planted with this hybrid. The buffer space accommodated 3 rows about 250 feet long. Thus, the hybrid beet occurred at about 60-foot intervals as strips across the experimental field. One of these buffer areas was between the second and third replications of the 8-variety, agronomic evaluation test of leafspot resistant varieties. The 3-row strip of the hybrid was harvested for comparison with the evaluation test. The sucrose percentage of the hybrid was 12.52 and the calculated acre yields were 18.17 tons of

roots and 4,547 pounds of gross sugar. In comparison, the general means of the whole agronomic evaluation test were 13.90 percent sucrose, with acre yields of 14.26 tons of roots and 3,967 pounds of gross sugar. Since several of the 8 varieties in the evaluation test produced in excess of 4,000 pounds gross sugar per acre, the yield of the hybrid may not be significantly above that of conventional sugar beet varieties, but the hybrid was undoubtedly as good as any of the conventional varieties in this test. However, the low sucrose percentage of the hybrid is a serious disadvantage.

In general, the performance of the hybrid was in agreement with the yields obtained from the $F_3$ of this hybrid and from $F_3$ to $F_7$ generations of a similar hybrid that has been in many tests since 1936. Briefly, during this period the sugar x red garden beet hybrid varieties have usually surpassed the standard sugar beet check variety in root yields, frequently by highly significant margins. However, due to consistently lower sucrose percentage of the hybrid, yield of gross sugar has exceeded that of the sugar beet check in only slightly more than one-third of 70 comparisons that were made. Instances in which the yield of gross sugar from either the hybrid or the sugar beet check variety has significantly exceeded the yield of the other have been rare.

Since the desirability of a beet with predominantly short roots was not foreseen this character had been disregarded in the selections made to date in the sugar beet-garden beet hybrids. However, even in the case of the hybrid carried to the $F_7$ by continued selections, the roots of the seventh generation are predominantly shorter and thicker than those of conventional sugar beet varieties.

It is probable that a number of genetic factors determine root shape in beets. Observation of inbred lines of hybrid origin indicates that the characters for true flat- or globe-shape may be simple recessive factors, readily manipulated by the plant breeder. On basis of work done to date, it should not be difficult to obtain a hybrid variety with white flesh and globose roots that would equal or exceed our present sugar beet varieties in root yield.

There remains the matter of sucrose content of the hypothetical sugar x red garden beet hybrid. To date, the best that can be said for the hybrids is that they have not been definitely unsuitable for sugar production. Occasionally in some test a hybrid line has been equal in sucrose percentage to a yield type of sugar beet included as the check variety. In general the hybrids have had a sucrose percentage that was from one-half point to as much as two points less than that of the sugar beet check variety. This relationship has held rather consistently throughout a fairly wide range of comparative tests.

Selection for sucrose content after the $F_3$ in these hybrids has maintained, or, at best, only slightly increased the gain secured by careful selection in the $F_2$. On the basis of a single test, random increase of one of these hybrids from the $F_3$ to the $F_6$ resulted in no change in the sucrose

percentage and a small, statistically non-significant reduction in root yield. From the evidence at hand it is doubtful if selection alone in a sugar beet-garden beet hybrid will produce a hybrid variety that is fully satisfactory as to sugar content. Apparently backcrossing to a high-sugar sugar beet variety with rigid selection in the backcross generations for root yield and root shape is indicated.

It has been observed that these hybrid varieties are much more subject to a physiologic cracking of the roots and to attack by bacterial pocket *(Pseudo-monas beticola)* than the sugar beet varieties with which they have been grown. The 1947 crop of one of the lines of the selection project previously mentioned had over 20 percent of roots showing from a trace to severe cracking. Certain of lines have also produced crops with relatively high percentages of the roots having galls or over-growths particularly on or near the crown. This is a matter that will need attention.

The breeding investigations with these varieties show that selections for the customary economic characters have resulted in varieties that are predominantly globe- to top-shape. Root yields of the varieties have been high. Sucrose percentages usually have been so much below those of commercial varieties of sugar beet as to nullify any effects from the high root yields. In other words, gross sugar yields were, at best, about equal to the yields of standard varieties. Hence the varieties now available from hybridizing sugar and red garden beets; although superior for machine harvest, may not displace conventional sugar beet varieties. In some more northern districts where obtaining high root yields is the principal problem, these varieties may find acceptance. There is need for additional trials on a large scale of the globe- or top-shaped types to appraise the advantages in machine harvest as against other considerations. There is, of course, immediate need for improvement of the varieties without sacrifice of the desired root shape.

## Discussion

The possibilities of obtaining a sugar beet variety with root conformation suitable for machine harvest from our present sugar beet varieties should be thoroughly explored. In the early stages of a selection program, mass selection can be very useful in quickly concentrating enough of the desired character in a variety that can be used while the ideal variety is sought by more detailed methods.

The inbred lines of sugar beets now in existence should be re-evaluated as to the shapes of their roots. New sources of genes for root shape should be tapped to obtain strains improved in root shape. It is unlikely that all the factors responsible for the apple-, radish- and pear-shaped roots noted by Achard in the progenitors of the White Silesian beet have been entirely lost from sugar beet stocks.

Seemingly unpromising possibilities should not be neglected. An example is a recessive abnormality tentatively called "celeriac root" that appeared in an inbred beet line at Fort Collins. This beet consists of little

more than a greatly over-developed crown with a relatively small amount of gnarled root tissue, the whole growing practically on the surface of the ground. This utterly worthless beet when crossed with normal sugar beets produced an excellent $F_1$ having roots of ideal shape for machine harvest. In the $F_2$ approximately one-fourth of the roots were of the celeriac parent type and the remainder were predominantly more or less similar to the $F_1$ roots. When this cross was grown a number of years ago no further selections were made. However, it is entirely possible that an excellent short-rooted beet variety could be obtained from this cross.

## Summary

Short, globe- or top-shaped sugar beet roots appear to offer distinct advantages in the mechanization of sugar beet harvest. Varieties approximately equal to sugar beet varieties in gross sugar production and having the desired shape have been obtained by selection from the hybrids between sugar and red garden beets. In general, superiority of the hybrid variety in root weight is nullified by lower sucrose percentage. Additional appraisals are necessary to determine if the advantages with respect to harvesting are enough to over-balance the lower root quality. Breeding to improve the quality of the sugar x red garden beet hybrid is continuing. If the hybrid itself is not susceptible to improvement it may constitute an improved gene source. Although the factors responsible for short, globose root shape are certainly in the minority in present-day varieties, it is unlikely that they have been completely eliminated. Plant breeders should make an intensive search for these factors.

# Thermal Induction and Reversal in Relation to Beet Seed Production[1]

RAY A. PENDLETON[2]

STUDIES WITH BEET SEED production in various parts of the country have resulted in considerable accumulated knowledge of the temperature and light requirements to promote seedstalk formation in the biennial sugar beet plant. The subject has been reviewed in detail by Owen, et al. (1)[3].

Where beets are grown by the field-overwintering method it is desirable that induction of flowering be sufficient to insure all plants entering into seed production so as to maintain the varietal characteristics. Under western Oregon climatic conditions with late summer planting, induction of flowering is practically complete. Individual roots are generally rather small when winter dormancy is reached. Seedstalk formation starts with the resumption of spring growth, after which there is no further increase in root size.

Where beets are transplanted for seed production, as is the case with most red beets and some sugar beets, production per plant needs to be high to obtain economical yields with feasible transplanting rates. Seed yield per plant is to a high degree positively correlated with the size of the root, provided the root is in good growing condition. Under optimum conditions very large seed yields have been obtained with transplanted large size mother beets. However, it is not feasible to store very large roots in sufficient quantities for transplanting purposes.

Small beets that would grow and build up more food reserves and still produce seed well would be preferable to large beets for transplanting. It is possible to accomplish this with red beets. Plants completely thermally induced, as when stored at 40° F. over winter, can be made to revert partially toward the vegetative condition by holding them at somewhat higher temperatures for a time just prior to transplanting. After transplanting, increase in growth and food reserves will go on while the additional thermal induction necessary for flowering is being acquired. A comparable effect results with beets overwintered in the field and transplanted directly after short seedstalks have developed and been cut back. In such plants the apical dominance of the terminal bud generally results in so much suppression of the axillary buds that these do not grow sufficiently to acquire enough thermal induction to make them develop into seedstalks

[1]The experimental work was done in cooperation with the Oregon Agricultural Experiment Station and represents a joint contribution of the United States Department of Agriculture and that Station.

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[3]The numbers in parentheses refer to literature cited.

immediately after the removal of the apical shoot permits them to grow. While these axillary buds are growing vegetatively in the spring and acquiring the degree of thermal induction necessary for flowering, the roots increase in size and store more food reserves. Such increase in food reserves makes possible more seed production than where plants with complete thermal induction are allowed to bolt and flower directly after transplanting. Figure 1 shows the contrast in size of roots between a plant that went into the reproductive phase as soon as transplanted and two that made extensive vegetative growth before developing flowers.

Figure 1.—Detroit Dark Red table beets. Plant at left went into reproductive phase promptly after transplanting and without increase in root size. Other two plants had adequate thermal induction delayed and made extensive vegetative growth after transplanting and before flowering.

The results of an experimental test with red beets given different treatments before being transplanted are summarized in table 1. In this test the beets overwintered in the field had seedstalks about 6 inches long when transplanted. These seedstalks were cut back in one treatment and retained in the other. Those beets carried over winter in storage at 40° F. were held for about 2 weeks prior to transplanting at a mean temperature of about 48° F. The three lots of roots were fairly uniform in size at transplanting and averaged about 110 grams in weight.

Partial reversal of thermal induction or complete thermal induction prior to transplanting resulted in increased growth and accumulation of food reserves in the spring and consequently in increased seed production.

Table 1.—Results with transplanted table beets, 1946.

| Method of overwintering | Root size at harvest | Plants fruiting | Seed yield | |
|---|---|---|---|---|
| | | | Per plant | Per acre |
| | grams | percent | grams | pounds |
| Stored at 40° F.[1] | 610 | 72 | 110 | 1,510 |
| In the field[2] | 327 | 88 | 105 | 1,930 |
| In the field[3] | 116 | 96 | 49 | 830 |

[1]Shifted to outdoor temperatures with mean of about 48° F. for 2 weeks before transplanting.
[2]Terminal seedstalks about 6 inches long cut back just before transplanting.
[3]Terminal seekstalks about 6 inches long not cut back.

Further evidence was afforded by field observations in 1947 in several red beet fields. A summary of conditions and yields is given in table 2.

Table 2.—Field results with transplanted table beets.

| Transplanting date | Plants per 100 feet | Root weight per 100 feet | Plants fruiting | Seed per acre |
|---|---|---|---|---|
| | | pounds | percent | pounds |
| February 20 | 60 | 15[1] | 100 | Not harvested |
| March 5 | 53 | 27 | 100 | 900 |
| March 18 | 56 | 58 | 95 | 2,000 |
| April 25 | 36 | 25 | 60 | 1,200 |

[1]These made no further growth after transplanting.

The plants in the field transplanted February 20 were so small, as a result of not growing in the spring, that an unsatisfactory crop of seed resulted. The plants transplanted March 18 made the greatest growth and gave the highest yield. Only 60 percent of those plants transplanted April 25 bolted but these gave a fair yield.

A fifth field was transplanted about May 1 with roots that had been stored in outdoor pits. About 2 weeks before transplanting these roots were removed to sacks where they tended to heat slightly. As a result they reverted to vegetative condition to such an extent that not over 30 percent produced seedstalks. The field was later abandoned.

The above observations indicate rather clearly that good yields of seed from transplanted table beets are associated with some retardation or reversion of the bolting tendency which is developed from field-overwintering in this climate or warehouse storage at 40° F. for 3 or 4 months. More investigation will be necessary to determine the exact conditions required to produce the desirable amount of retardation or reversion.

### Studies with Reversion in Sugar Beets

The sugar beet varieties studied react to thermal treatments or cutting back the terminal bud in a manner comparable to that of the table beets but not to the same degree. Some preliminary trials were made in 1944 and 1945 of cutting back the terminal shoots in early spring after seedstalk initiation. A more branching seedstalk formation was secured but reduced seed yields resulted. In 1947, further trials in which combination thermal treatment and cutting back the terminal shoots were made to determine

the effect on reversion of bolting. Transplanting, either with or without topping, and topping without transplanting in January or February produced no appreciable effect. However, when transplanted roots were held in the greenhouse for 10 days prior to transplanting in February, there was appreciable vegetative stimulus. Topping and transplanting in early April caused a moderate increase in vegetative activity but only small increased seed yields.

Except for some large mother beets, reversal of bolting in sugar beet roots under treatments thus far tried has not resulted in seed yields per plant which would be satisfactory for common transplanting conditions. Further information is needed on this point and investigations are being continued.

## Summary and Conclusions

Both table beets and sugar beets grown for seed show a high positive correlation between size of root and seed yield per plant.

It is not feasible to store sufficient quantities of large roots for transplanting purposes. Therefore, where seed is to be grown from transplanted roots, it is desirable that more root tissue develop after the roots are transplanted.

This effect can be accomplished by retardation or partial reversal of thermal induction provided it can be held under control.

Topping back table beets transplanted in April had the effect of greatly stimulating vegetative growth and seed yield.

Progressive delay of transplanting stored table-beet roots caused corresponding increase in reversal of bolting and increased seed yield per plant, provided such delay was not carried to the point that a completely vegetative condition resulted.

Reversal of bolting in table beets could also be effected by short periods of exposure to warm greenhouse temperatures before transplanting, or by longer exposure to medium range outdoor temperatures.

The sugar beets studied show the same type of behavior as table beets in reversal of bolting but apparently not to the same degree.

It seemed to be much more difficult to control and hold uniform reversal in sugar beets than in table beets.

Topping sugar beets after seedstalks have been initiated in early spring has in most cases either reduced yield of seed per plant or caused a high mortality in the plants so that total yield was reduced.

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# Changes in Root Weight of Sugar Beets During Their Reproductive Phase

J. M. Fife and Charles Price[1]

Under some conditions sugar beet roots grow very little during the reproductive phase and under other conditions they may grow appreciably. Pultz (1)[2] in his study of field-overwintered plantings of U.S. No. 1 (an easy bolting variety) conducted near St. George, Utah, found little increase in root weight of the unthinned sugar beets after seed production began. The plantings were made August 23 and September 15 and included two fertility levels. The same results were obtained irrespective of planting date or whether or not the plants were fertilized with nitrogen. In other tests by Pultz, sugar beet plants that were thinned to single plants, standing 12 inches apart in the row, showed considerable increase in weight of roots during the reproductive phase. The increase in weight was greatest in the roots that did not receive nitrogen fertilizer.

The authors' observations also have shown a diversity in plant reactions dependent on conditions. In order to obtain further information, studies have been conducted to determine some of the factors involved.

Sugar beet seed production in the United States is chiefly by the field-overwintering method. Seed fields are planted in the late summer and the small sugar beet plants are left unthinned and undisturbed until the seed is harvested the following summer. In the conventional method, the seed is produced from mother beets or from stecklings. Seed is planted in the spring or early summer; the roots are dug in the fall and stored under cool conditions over the winter. The roots are then transplanted in the early spring in the seed field. Under the conditions of temperature, ordinarily experienced in most seed-producing districts, stored roots and those overwintered in the field acquire sufficient thermal induction to initiate and complete the reproductive phase. The experiments to be reported employed varieties that readily produce seed under the winter conditions of southern California.

## Experiments with Field-Overwintered Sugar Beet Roots

In an experiment conducted in 1943-1944, an annual type of sugar beet (SL 2850) was grown at two fertility levels. The plot held at the lower-fertility level received no barnyard manure but 800 pounds of ammonium sulphate was applied. For the higher-fertility level, barnyard

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[2]The numbers in parentheses refer to literature cited.

manure was applied to a plot at the rate of 20 tons per acre, and, in addition, ammonium sulphate was applied at the rate of 1,800 pounds per acre.

The seed was planted September 27, 1943, on 12 single-row beds, 20 inches apart. Each row was 84 feet long. The plants were thinned at the 4- to 6-leaf stage to stand approximately 8 inches apart in the row. Roots were dug from the high- and the low-fertility sections of the plot at intervals from the time the roots were thinned until the seed was mature. The roots were topped at the lowest leaf scar and weighed individually. The first bolters appeared the last week in March, 1944, and by April 22 all of the plants had produced seedstalks. These averaged 38 inches high.

To obtain more reliable data on root weights, large numbers of roots were dug and weighed individually at four criterion periods, December 17, January 19, March 23, and June 29 (harvest time). The numbers of roots taken at these dates were 207, 145, 236, and 423, respectively. Samplings at other dates (see figure 1) consisted of 20 roots. In view of the fact that no significant differences were found between the weights of the roots as taken from the two fertility levels, only mean root weights will be reported.

The growth of the roots from the time they were thinned until the seed was harvested, as revealed by the samplings, is shown in figure 1. Observations made during the test and the meteorological records indicate that the conditions were such as would promote complete fructification

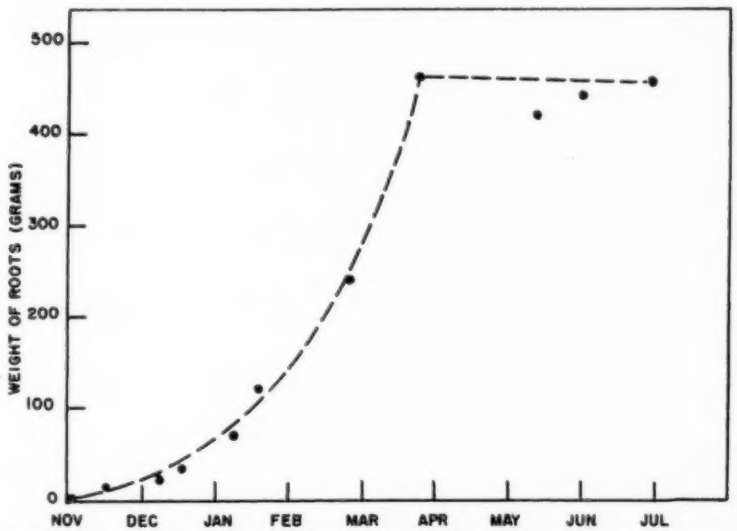


Figure 1.—Root weights of field-overwintering sugar beets (SL 2850) from the thinning period until harvest. Data were obtained from a series of samplings of the 1943-1944 experiment. The smooth curve shown was not fit to the data and therefore only indicates the trend.

of the variety SL 2850. The data as given in figure 1 show, therefore, that these roots receiving sufficient photothermal induction to insure production of seedstalks abruptly stopped growing when the reproductive phase began.

Corroborative evidence of the same general character was obtained in a replicated test conducted in 1944-1945 with the sugar beet variety U.S. 33. This variety, although requiring more photothermal induction than SL 2850, is known as an easy bolter, and its seed production under California conditions usually involves a high population of the seed field.

An experiment on sugar beet seed production was set up consisting of manure versus no-manure treatments upon which were superimposed three levels of nitrogen as obtained by applying sodium nitrate in differential amounts, several times during the season. For the three levels set up, the applications totaled, as acre rates, 380, 800 and 2,200 pounds for the low, medium and high-fertility levels, respectively. The plots were 8 rows wide and 35 feet long, and were arranged as a 6-times replicated randomized block. The seed was planted August 23, 1944, and the plants thinned to a distance of 6 inches in the row at the 4- to 6-leaf stage. The first seedstalks appeared the last week in March, 1945. Bolting counts made during the early part of the reproductive phase showed that at least 95 percent of the plants produced mature seed.

For studies on the rates of growth of the roots, a series of 10 samplings was made over the entire experimental area. On February 9, a total of 180 roots, 5 per plot, was taken to determine the average size of the roots at the time when rapid growth was just beginning to be resumed in the spring and well before seedstalk formation began. There was no significant difference in weights of roots from the different fertility levels; in subsequent samplings no significant effects attributable to fertility levels were found. For simplicity, the data are combined and reported as simple averages for all treatments.

Samplings were made during the reproductive phase, 2 roots being taken each time from the plots making a total of 72 roots (36 from manured, 36 from non-manured portions). After bolting was well advanced, only those plants producing normal seedstalks were sampled; at the last sampling when the seed was matured, all the roots of the center rows of each plot that had bolted were weighed. This sampling involved approximately 100 roots from each plot, making a total of approximately 3,600 roots. The results of the experiment are shown in figure 2.

From February 9 to March 16, the roots increased in weight approximately 75 percent. From March 16 until the seed was harvested, no significant change in the weight of the roots occurred. The solid line (figure 2) is the linear regression line computed from the data on root weights from the samplings on March 16, just prior to bolting, to June 23, when the seed was harvested. As in the previous test, the sugar beet roots, that had acquired sufficient thermal induction for complete bolting, did not make significant amounts of growth during the reproductive phase.

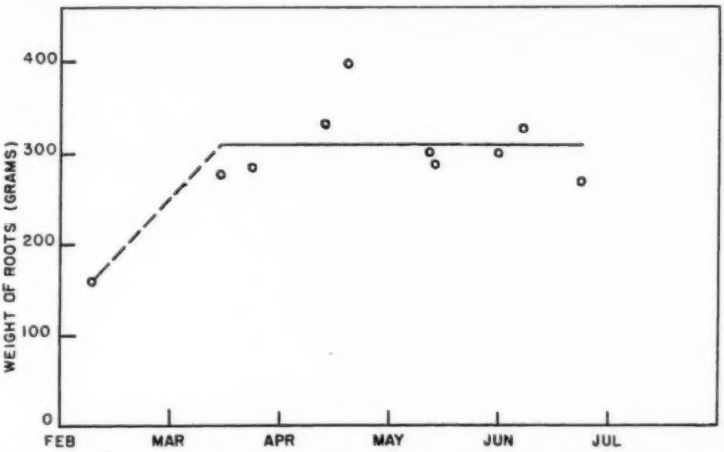


Figure 2.—Average root weights of field-overwintered plants of the sugar beet variety U.S. 33 prior to and during the reproduction phase in the experiment conducted in 1944-1945. The broken line indicates the trend before growth ceased, the solid line is regression line computed from the data for March 16 to June 23.

## Experiments with Transplanted Sugar Beets

Approximately 1400 roots were obtained from Salt Lake City, Utah.[3] The seed to produce the stecklings was planted in a seed plot July 31, 1942, and the roots were dug January 14. The small stecklings were taken from unthinned sections of the plot whereas the large stecklings were dug from thinned sections of the plot. Mother beets included in this study were dug in the fall from thinned plots which had been planted in the spring of 1942. These roots were stored in a root cellar until transplanted in the spring. One hundred roots ranging in size from 15 to 45 grams with a mean weight of 29.1 grams, were divided into 20 five-root groups, the roots in each group having approximately the same weight. A similar number of roots with a mean weight of 110.6 grams and a third group of large roots having a mean weight of 1,103 grams were also divided into 20 five-root groups. The test was conducted at two nitrogen-fertility levels. The lower of these appeared to be adequate for normal growth because the higher-fertility level did not increase the growth of the roots. The results for the two fertility levels have been combined, and only mean values are reported. The 5-root groups of the small, medium and large beets were transplanted February 2, 1943, in a randomized-block arrangement on the high and low-fertility section of the plot. When the seed was mature all the roots of the small and medium-sized beets that had produced mature seed were weighed individually and the mean increase in weight calculated, using as the weights at transplanting time the mean values 29.1 for the small roots and 110.6 for the medium-sized roots. The large beets had been

[3]These sugar beet roots were furnished by Bion Tolman, formerly of this Division.

weighed individually and the weight recorded on the root at transplanting. They were again weighed individually and the increase in weight determined for each root. The gain in weight of the transplanted roots during the reproductive phase and the bolting data are shown in table 1.

**Table 1.**—Increase in weight of transplanted sugar beet roots (U.S. 22) during the reproductive phase in relation to root sizes and to the percentages of roots bolting and producing seed.

| Year and place roots were grown | Mean weight of roots at transplanting | Average gain in weight of roots | | Plants bolting | Plants producing seed |
|---|---|---|---|---|---|
| | grams | grams | percent | percent | percent |
| 1943—Salt Lake City, Utah | 1103 | 217 | 19.7 | 78 | 68 |
| | 110.6 | 134 | 121 | 72 | 68 |
| | 29.1 | 139 | 478 | 55 | 44 |
| 1945—King City, California | 1064 | 110 | 10.3 | 100 | 93 |
| | 841 | 89 | 10.6 | 99 | 97 |
| | 643 | 71 | 11.0 | 100 | 97 |

Another test conducted in 1945 is also shown in table 1. Sugar beets (U.S. 22) were taken from King City, California, and stored for a period under conditions favorable for thermal induction to take place. These roots were divided into groups of three sizes, each containing 120 roots. The mean weights of the roots, comprising the three different sizes, were 643, 841 and 1,064 grams. The roots were weighed individually and the weight recorded on them at the time of transplanting. The roots of each size class were subdivided into 12 ten-root groups so that each group had about the same range in root size and approximately the same total weight. Six 10-root groups of each size class were transplanted in a randomized block on each of the two nitrogen-fertility levels. When the seed was mature the roots were topped at the base of the seedstalk and weighed individually. The increase in weight of each root was determined by reference to its initial weight. The differential fertilization proved to have no effect on the root growth during the reproductive phase, consequently mean values only are reported.

In these two tests the increase in weight of the transplanted roots during the reproductive phase was least when thermal induction was sufficiently complete so that a high percentage of the plants produced seed. In the 1945 test, in which 93 to 97 percent of the plants produced seed, the roots increased in weight approximately 10 percent. In the 1943 test, in which only 44 percent of the roots of very small size produced seed, the increase in weight that occurred in the roots producing seed was 478 percent. The very small roots that did produce seed bolted later than the larger roots, and increased more than four fold in weight. The gain in weight of the medium-sized roots (110.6 grams) also was striking.

A third test was conducted with transplanted roots during the season of 1946-1947 to determine the weight increase of sugar beet roots during the reproductive phase, the roots being of the same age but differing in size. A planting of the variety U.S. 33 to supply the roots for the test was

made at Riverside, California, February 13, 1946. The plants were grown under the same environmental conditions except for space allotments. Some plants had wider spacings in the rows and consequently made more growth. On December 15, 180 roots ranging in weight from 29 to 759 grams were taken for the test. The roots were segregated by weight into 36 five-root groups. Each group consisted of roots of very nearly the same weight. The roots were packed in moist sphagnum moss and stored for thermal induction at 40° F. for 86 days. The roots were transplanted on March 13, 1947, in a field plot in which a high level of fertility was maintained. After the seed was mature, the plants were dug and weights of roots again determined. In figure 3, the mean increase in root weight for the 36 five-beet group is plotted against the corresponding root weight at transplanting. The regression line for gain of weight of roots on the weight of roots at transplanting is shown. The correlation coefficient, —0.655, is highly significant. It is evident from this test that the smaller the roots were at transplanting, the greater was their increase in weight during the reproductive phase.

## Discussion

The results obtained with field-overwintered plants of easy bolting varieties, in which photothermal induction was apparently adequate, indicated that root weights increased about as would be expected until the reproductive phase started when growth essentially stopped. The curves indicate that the change was abrupt. The regression line as determined from the data in 1944-1945 test with U.S. 33 showed that with 95 percent of the plants producing seed, the increase in weight after fructification began was not significant.

Tests with transplanted beets showed that the size of roots may be a factor influencing increase in root weight after fructification begins, but here also the degree of thermal induction seems a controlling factor. Roots ranging from 643 grams to 1,064 grams showed essentially the same percentage of gain in root weight when thermal induction, as revealed by the percentage of plants going to seed, apparently was nearly complete. On the other hand, small roots (110.6 grams average) and very small roots (29.1 grams average) whose thermal induction was such that only 68 and 44 percent of the plants, respectively, produced seed, gained respectively 121 and 478 percent in weight over the transplanting period weight. These data were based entirely on plants producing mature seed. Observations were made that the small roots that produced seed bolted more slowly than the larger roots.

The extensive experiment in which presumably the thermal induction was adequate, and in which the gain in weight of roots was found to be negatively correlated with root weight at transplanting time, probably can be interpreted in light of the preceding experiments.

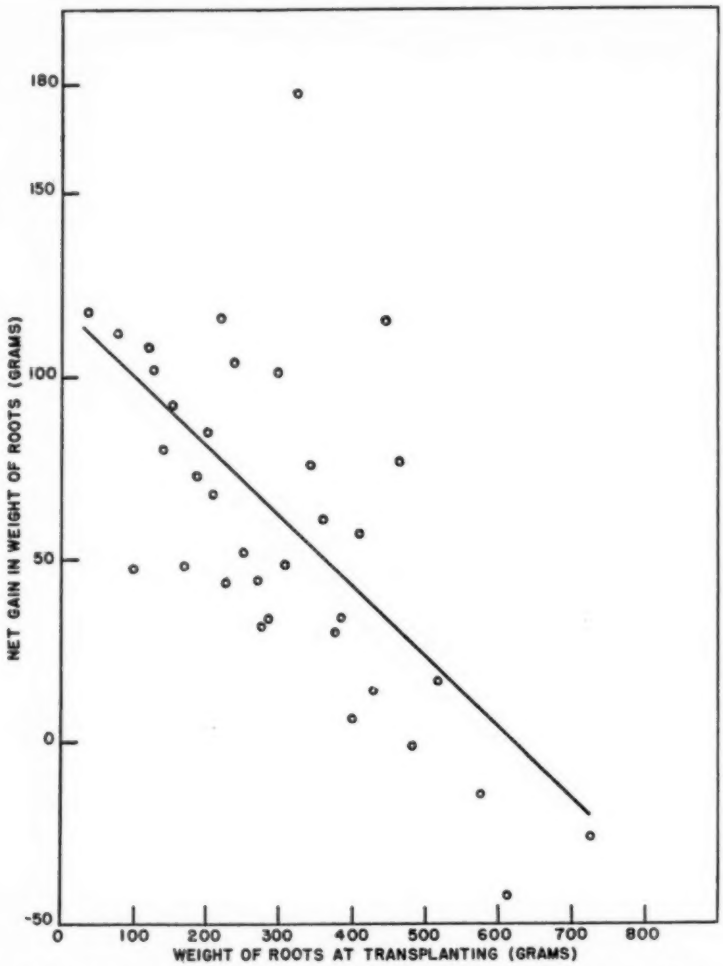


Figure 3.—Gains in root weight during the reproductive phase are plotted against the corresponding root weights at transplanting time. The regression line is shown. The data are taken from the 1946-1947 experiment in which roots were stored 86 days at 40° F. prior to transplanting.

The fact that in a test where the degree of reproduction indicated inadequate induction there was striking increase in weight of roots and that the increase appeared to exhibit an inverse trend to the degree of thermal induction, suggests a relationship between thermal induction including the reactions it brings about and the continuance or discontinuance of vegetative development.

The fact that in the 1946-1947 test with transplanted roots where extensive thermal induction was given and all the plants bolted, the smaller beets in general showed more increase in root size than did the larger beets may indicate that there is a size factor influencing the acquisition of thermal induction by sugar beets.

## Summary

Sugar beets of easy bolting type (SL 2850 and U.S. 33) were grown for seed production by the field-overwintering method under conditions that brought about essentially complete reproduction. The roots of these sugar beets did not continue to increase in weight after the reproductive phase began. By contrast, sugar beet roots in which the degree of reproduction indicated inadequate thermal induction increased in root weight, the greatest increase occurring in small roots. In another test, extended thermal induction treatment was given prior to transplanting the roots for seed production. All plants produced seedstalks. Some gain in root weight occurred after transplanting. There was a significant negative correlation between the gain in weight and the root weight at time of transplanting. This may indicate that root size is an important factor in the thermal induction process.

## Literature Cited

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1937. Relation of nitrogen to yield of sugar-beet seed and to accompanying changes in composition of the roots. Jour. Agr. Res. 54 (9): 639-654.

# Spacing Sugar Beets for Seed Production[1]

RAY A. PENDLETON[2]

SPACING OF BEETS for sucrose production has long been studied and optimum stands fairly well determined. Spacing of beets for seed production has received less attention. In America, sugar beets for seed have been mainly grown by the field-overwintering method, whereby from 10 to 20 pounds of seed per acre are planted in late summer or early fall and left unthinned. Close spacing is necessary in some of the seed-growing areas to shade the soil and keep it as cool as possible. Observed yields of seed under varying conditions in northern California, Oregon and Washington suggested the desirability of study to determine the optimum space relationship for highest seed yields. Such relationship involving both soil and light would be influenced by the plant distribution as well as the total population.

Widely spaced transplanted sugar beets have been grown which yielded well over a pound of seed per plant, providing heavy yields with relatively few plants. In contrast, similar high yields of seed have been produced with field-overwintered stands of 10 to 12 plants per foot of row. In the coastal climate of the Pacific Northwest the field-overwintered plants tend to start seedstalk formation as soon as the days get relatively long and spring growth starts, after which there is comparatively little more root enlargement.

Optimum plant spacing is no doubt influenced by soil fertility, moisture supply and time of planting. Close spacing to shade and keep the soil cool is not necessary under the climatic conditions where these studies were conducted.

## Irrigated Conditions

Two trials under irrigated conditions may be cited. Other tests were conducted but vitiating factors rendered the results less satisfactory. Stand counts were taken at harvest time. In a 1941 trial in the Willamette valley of Oregon, with rows spaced 24 inches apart, a wide variation in plant population was noted. The lowest was 16,335 beets per acre based on a 75 percent stand of 12-inch singles, and the highest 348,480 beets per acre in continuous stand averaging 16 plants per foot. Included were two blocked stands, one with 87,120 beets per acre in hills spaced 12 inches apart averaging 4 beets each, and the other with 65,340 beets per acre in hills spaced 20 inches apart averaging 5 beets each. There were 12 replications of the spacing treatments.

[1]The experimental work was done in cooperation with the Oregon Agricultural Experiment Station and represents a joint contribution of the United States Department of Agriculture and that Station. Published as Technical Paper No. 529 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Farm Crops.

[2]Associate Soil Technologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

The 1947 trial was in the Medford area with rows spaced 20 inches apart. Plant populations varied from a low of 32,670 beets per acre in 12-inch singles and 24-inch doubles to a high of 261,360 beets per acre in continuous stand averaging 10 plants per foot. Included was one blocked stand with 104,544 beets per acre in hills spaced 24 inches apart averaging 8 plants each. There were six replications of these treatments.

The blocked stands averaged about one plant per inch of row within the block. The spacings tried, together with the approximate total plant population and seed yield, are given in table 1.

**Table 1.—Seed yields with various spacings under irrigated conditions.**

| Spacing | 1941[1] | | 1947[3] | |
|---|---|---|---|---|
| | 24" rows plants per acre | Seed per acre | 20" rows plants per acre | Seed per acre |
| | | pounds | | pounds |
| 12" singles | 16,335 | 1937 | 32,670 | 2405 |
| 6" singles | 32,670 | 2191 | 65,340 | 2610 |
| 3" singles | ---- | ---- | 104,544 | 2577 |
| 12" hills (averaging 4 beets) | 87,120 | 2264[2] | ---- | ---- |
| 24" doubles | ---- | ---- | 32,670 | 2442 |
| 20" hills (averaging 5 beets) | 65,340 | 2101 | ---- | ---- |
| 24" hills (averaging 8 beets) | ---- | ---- | 104,544 | 2532 |
| Unthinned | 348,480 | 1934 | 261,360 | 2250 |
| Significant difference (19:1 odds) | ---- | 240 | ---- | 402 |

[1]Variety U.S. 200 x 215 planted September 3, 1940.
[2]Statistically higher yield than the unthinned.
[3]Variety U.S. 15 planted August 14, 1946.

The results of the 1941 test showed higher yields from the spaced beets than from the continuous dense stand except in the case of the singles 12 inches apart. In the last named treatment downy mildew was more of a factor than in the other spacings. The treatment with hills of 4 beets 12 inches apart gave 330 pounds of seed per acre more than the unthinned plots with 16 beets per foot. This difference is statistically significant at the 5 percent level. In the unthinned plots only 65 percent of the plants participated in seed production. About half the remaining 35 percent failed to bolt, while the other half bolted but produced no seed. Observations in other fields indicated that the late planting as well as the density of the stand influenced the performance of the unthinned beets.

The 1947 test near Medford gave average increases in the thinned over the unthinned check of 155 to 360 pounds of seed per acre but due to the wide variation in yields among the replications the differences did not reach statistical significance. A severe epidemic of *Ramularia* leafspot almost completely defoliated the plants in all treatments late in the spring and may have affected the yields of the different treatments unequally.

The trend of the yields indicates that stands of 2 to 6 plants per foot of row give the best yields with late summer and early fall plantings.

Some studies of rate of growth and sucrose content were made. The evidence suggests that the highest sucrose content is reached in early spring after which there is a gradual decline until harvest. Small beets in thick stands tend to have slightly higher sucrose than large beets in thin stands. In the Medford trial the roots tended to increase in size until May but in the Willamette Valley the roots usually reached maximum size by March.

### Non-Irrigated Conditions

A number of trials have been conducted with non-irrigated beets in the Willamette Valley to determine optimum plant populations for highest seed yields. Plant populations have varied from a low of about 125 plants to a high of about 1,000 plants per 100 feet of row in 24-inch row spacings. Some have dealt with continuous stands and some with hills spaced at 12 and 24 inches. With one exception, in which the lowest plant population gave slightly lower seed yields, there has been no appreciable difference due to spacing variations. Further study of spacing under non-irrigated conditions is needed.

When beets were grown in hills, spaced at 24 inches with an 8-inch block left, maximum yields were obtained with 3 to 8 plants per hill with no appreciable difference within this range. There was no correlation between number of plants per hill and total weight of root per hill. The thinner stands tended to compensate for their greater space allotment by making more growth per plant. This study was conducted in 1944.

In 1945, an experiment was conducted to determine the optimum number of plants grown in hills spaced 24 x 24 inches. This was under irrigated conditions in the Willamette Valley. Results were similar to those with non-irrigated beets. Maximum yields were obtained with 3 to 8 plants per hill with little spread within this range. Less than three plants resulted in lower yields per hill. There was a high degree of correlation $r=0.702$ between total weight of root per hill and seed yield but no correlation between number of plants per hill and total root weight.

### Summary

In continuous stands the optimum plant population in the Pacific Northwest seems to lie in the neighborhood of 2 to 6 plants per foot of row. Where beets are blocked the population may be increased to about 1 plant per inch of row within the block.

Under western Oregon conditions, the roots in June-planted fields reached their maximum growth by early spring before bolting started. Late August and September plantings, by contrast, showed additional root growth in spring. Varieties low in bolting tendency, those requiring extensive thermal induction, bolt better if planted in June than when planted in late August or September.

The maximum sucrose content is probably also reached in early spring, after which there is a gradual decline.

A high degree of correlation has been shown between total weight of root per unit area and seed yield. However, within moderate limits very little correlation has been shown between plant population and total weight of roots.

# Fertilization and Time of Planting as Related to Yield of Sugar Beet Seed in the Hemet, California, Area

IRWIN E. FARRAR[1]

SINCE 1931, when the first crop of sugar beet seed for commercial production was planted in the Hemet area, constant search has been made to find the optimum crop rotation and fertilizer practice as well as the best planting dates, as both these factors are known to be of great importance in both the yield and quality of seed.

Chas. H. Price,[2] during the seasons of 1932 to 1940, demonstrated in his experimental plots near Hemet the value of nitrogen and manure. His later work showed the value of cover crops. Seed growers, however, have used cover crops in a very limited way, a practice mainly due to the close-by supply of dairy and poultry manures at favorable prices.

Field experiments near Hemet with various forms of commercial fertilizers, were started by the writer in 1935. These tests were mainly carried on by the strip-plot method, replicated at least three times. Plots were always harvested, threshed and cleaned separately. The following conclusions can be drawn from the results:

1. Phosphate in the form of ammonium phosphate, both 16-20-0 and 11-48-0, gave no increase either in yield or germination. Nitrogen was maintained at the same level in the check plots, the nitrogen being furnished in the form of sulphate of ammonia. Treble superphosphate broadcast immediately before planting at the rate of 200 pounds and 300 pounds per acre gave no increase in yield.

2. A 2-year experiment compared three mixes of complete fertilizer (4-12-10, 5-12-6 and 6-10-12) with sulphate of ammonia, the amount of nitrogen applied being the same in all plots. No worthwhile differences appeared.

3. Of late many growers have tried a complete 6-9-6 fertilizer, applied as soon as possible after planting. There has been no apparent benefit over simple nitrogen.

Many tests have been carried on to endeavor to find the best form of nitrogen and the best time for application. Price, in his work previously referred to, found that a pre-planting application of a limited amount of nitrogen was good practice; but that an early fall side-dressing, plus a

[1]Partner, Farrar-Loomis Seed Co., Hemet, California.
[2]Agronomist, Division of Sugar Plant Investigations, United States Department of Agriculture, Riverside, California.

like amount in the spring, gave equally good results. He used in these experiments 80 to 120 pounds of nitrogen per acre, in the form of sulphate of ammonia.

Field work by the writer has been carried on with nitrogen in various forms—calcium nitrate, sodium nitrate, uramon, liquid ammonia ($NH_3$), ammonium nitrate, and ammonium phosphate (referred to above). It has been found that there is little difference in the value of any of these forms of nitrogen, if properly applied and timed. However, application of liquid ammonia ($NH_3$) is not practiced during the rainy season and nitrate of soda has a tendency to leach during the winter months. Since it has been available, ammonium nitrate has been widely used because it has the evident ability to give quick response combined with lasting results.

At the present time six field plots, widely scattered, are being checked to test the results of liquid ammonia ($NH_3$) applied at the rate of 60 pounds of nitrogen per acre drilled into the soil before planting. No apparent stimulus to early growth has been detected when compared to ammonium nitrate side-dressed as soon after planting as possible.

Experience over the years with various forms of nitrogen has led to the present recommendation of 160 pounds of nitrogen per acre in the form of ammonium nitrate or sulphate of ammonia, 60 to 70 pounds applied as early as possible after planting (some prior to planting, if possible) and 90 to 100 pounds in the spring in two applications, the first in late January or early February, and the balance drilled in just prior to bolting.

Gypsum at rate of 2½ tons per acre has proved its worth on heavier soils by increasing water penetration and promoting better soil condition. Two-year experimental tests showed a gain of 400 to 500 pounds of seed per acre on soils of slow water penetration.

The first tests with manure in commercial seed fields started in 1936. Small amounts were used at first with no outstanding results. In 1938 a large field experiment was carried on in an endeavor to show whether or not approximately 3 tons of pure dropping-board turkey manure would give justifiable results on a light soil that had a poor crop history. This experiment was conducted by strip-plot method with three replications, each plot being a little over ½ acre. Each plot was harvested, threshed and cleaned separately. Results showed the manured plots produced an average gain of 618 pounds of cleaned seed per acre, or a 28 percent increase.

Later work demonstrated that 3 to 4 tons of good-grade poultry manure or 6 to 9 tons of dairy manure on average good soil could be relied on to increase the crop by an average of 700 to 800 pounds per acre, with definite carry-over benefits to following crops.

On the basis of these findings some seed growers started in 1939 to apply manures to their soil, plowing it under about a month before planting, especially where alfalfa had not been a crop in the rotation.

To check the benefits of manures, alfalfa or other legumes, and nitrogen alone as related to yield of seed per acre, accurate field records have been kept on every seed field as follows: Prior crop history, amounts of manure and nitrogen used, and dates of application. Generally all fields have received ample amounts of nitrogen in suitable form, with the average amount per acre being gradually increased from 110-120 pounds per acre in 1941-42 crop (first year of these records), to 195 pounds per acre in the 1946-47 crop. Six crops were considered in this study. Fields, where insect damage was severe, were not considered. The fields have been segregated into three groups:

Fertility level No. 1—Good soil, ample manure, nitrogen.

Fertility level No. 2—Good soil, alfalfa or cover crop plowed under, nitrogen.

Fertility level No. 3—Good soil, no manure, no legume, nitrogen only.

The results of this 6-year study appear in table 1.

**Table 1.—Sugar beet seed yields as related to various fertility levels.**

| Year | No. 1 Yield in pounds per acre | No. 2 Yield in pounds per acre | No. 3 Yield in pounds per acre |
|---|---|---|---|
| 1941-42 | 2,979 | 2,849 | 2,111 |
| 1942-43 | 2,816 | 2,519 | 1,698 |
| 1943-44 | 3,142 | 2,490 | 1,816 |
| 1944-45 | 3,094 | 2,691 | 1,991 |
| 1945-46 | 3,239 | 2,613 | 2,082 |
| 1946-47 | 3,440 | 2,758 | 1,908 |
| Average yield | 3,118 | 2,653 | 1,968 |

In addition to the important increase in yield of seed per acre germination has averaged better in the higher fertility-level fields and the size of seed has been larger. The carry-over effect of the manure has been observed to last at least 2 years in following crops. The humus of the manure or legume together with the plowed under beet straw has constantly improved soil structure.

## Date of Planting

It was believed that the ideal planting dates were from September 10 to September 30 during the first years of commercial production of sugar beet seed. Earlier dates were attempted in 1936 with some plantings as early as August 29. This same year an experimental plot was laid out with seeding as early as July 1. As a result planting before August 20 was decided against, for the earlier dates gave no evidences of improvement, and the expenses entailed for additional irrigation, cultivation and care were high. Early dates also proved to be impractical from the standpoint of land preparation, especially if the previous crop was oats or barley.

For the season of 1936-37 all commercial fields planted between August 29 and September 10 showed an average of 3,390 pounds per acre; between September 10 to 20 the acre average was 3,090 pounds; and those seeded after September 20 produced an average of 2,182 pounds per acre. For the crop of 1937-38 the fields planted before September 10 yielded 3,160 pounds per acre; September 10 to 20 averaged 2,769 pounds per acre; and after September 20 only 1,800 pounds per acre.

Earlier planting dates had sufficiently demonstrated practical benefits so that seeding was started August 20, 1938, in some fields.

During the last 4 years the starting planting date has been August 15. September 15 is now the deadline, except in an emergency, or where partial replanting is necessary.

To again check the advantage of early planting as related to yield, a study was made of all fields which were graded in fertility levels No. 1 and No. 2 (as above described) for the three seasons 1943-1946. Fertility level No. 3 was eliminated so that fertility would be as nearly uniform as possible for this study. Results appear in table 2.

**Table 2.**—Planting date as related to yield of sugar beet seed.

| Year | Planted 8/15 to 9/5 | Planted 9/5 to 9/15 | Planted after 9/15 |
|---|---|---|---|
| | Yield in pounds per acre | Yield in pounds per acre | Yield in pounds per acre |
| 1943-44 | 3,155 | 2,630 | 1,582 |
| 1944-45 | 3,111 | 2,722 | 2,130 |
| 1945-46 | 3,261 | 2,553 | 2,410 |
| Average yield | 3,176 | 2,635 | 2,041 |

Early planted fields gave a 3-year average of 541 more pounds of seed per acre than the medium-period planting date and 1,135 pounds greater yield than the late-seeded fields.

## Summary

While all forms of nitrogen have given adequate results, ammonium nitrate and sulphate of ammonia are preferred in sugar beet seed production. Ammonium nitrate has the evident ability to provide quick response combined with lasting results. Nitrogen at the rate of 160 pounds per acre appears to give economic results. About 40 percent of this amount should be applied early to promote rapid fall growth, 30 percent added to the soil in late January or early February, with the balance drilled in just as bolting starts.

To date phosphate and potash have not shown their need as fertilizers.

Use of manures and legumes (either plowed under or used in crop rotation) has proved highly profitable to the sugar beet seed grower. When added to the soil in sufficient quantity, manures alone have increased the yield an average of 30 percent.

A 6-year study of soil-fertility levels has revealed that level No. 1 (manured fields) out-yielded level No. 2 (legumes) 465 pounds of seed per acre or 13.4 percent, and produced 1,150 pounds more seed per acre (59 percent) than level No. 3 (nitrogen only). The fertility level No. 2 seed crop was 685 pounds more per acre than level No. 3, or 34.7 percent.

Date of planting evidence consistently shows a greater yield of seed per acre for seedings made prior to September 5. Plantings should not be made after September 15 to 18. Previous findings have shown that quality of seed is improved by early planting.

For the Hemet area it is clearly evident that in order to obtain the highest yield of quality sugar beet seed per acre, planting should take place between August 15 and September 5 on fertile, manured soil, using 160 pounds (or more) nitrogen per acre during the growing season.

# Planting and Thinning

# 1947 Mechanical Thinning Tests

Bion Tolman, Ronald Johnson, A. J. Bigler,[1] Grant Nichol,[2] R. T. Nelson,[3] C. P. Parrish,[4] C. W. Doxtator,[5] H. P. H. Johnson.[6]

Mechanization of the sugar beet crop has developed rapidly during the past 5 years. However, mechanization of the harvest has progressed more rapidly than has mechanization of the spring work. Spring mechanization is dependent on many factors, some of the more important ones being the development and use of processed seed, the proper preparation of the seedbed, the development and use of precision planters, the control of spring weeds and the use of mechanical methods for thinning and subsequent weed control. This study deals with the factor listed last, namely, the use of mechanical methods for thinning and subsequent weed control.

Future steps toward spring mechanization will deal with procedures which will provide for increased uniformity of initial stands and the control of spring weeds. Procedures will be developed no doubt which will give control of spring weeds while beet populations are reduced mechanically.

Mechanical thinning tests conducted in 1946 showed some reduction in yield for treatments handled mechanically. The complete mechanical thinning treatment gave a yield of 8 percent less than the customary hand-block and thin treatment. The mechanical thinning treatment, however, cut down the spring labor requirement by 43 percent as compared to the hand-block and thin treatment.

The 1947 tests were designed to evaluate the effect of initial seeding rates on various methods of thinning. The objectives were: (1) to determine the seeding rate best adapted to various methods of beet thinning; (2) to determine the best spacing for various methods of beet thinning and (3) to determine the seeding rate and spacing most adaptable to complete mechanical thinning.

The treatments set up for common use in these experiments were:

1. Hand thinning at the 10 to 12 leaf stage (considered as average time of hand thinning).
2. Hoe thinning at the 4 to 6 leaf stage.
3. Cross-thinning with 8-inch centers at the 4 to 6 leaf stage.
4. Cross-blocking with 8-inch centers at the 4 to 6 leaf stage.

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5. Cross-thinning with 12-inch centers at the 4 to 6 leaf stage.

6. Cross-blocking with 12-inch centers at the 4 to 6 leaf stage.

7. Cross-thinning with 16 to 14-inch centers at the 4 to 6 leaf stage.

8. Best mechanical thinning and weed-control treatment that each area can devise.

It should be noticed with these treatments that emphasis was placed on timely mechanical thinning work as contrasted with the more or less common practice of waiting and using mechanical means as a last resort. It might seem that disadvantage was placed on treatment No. 1 by delaying thinning until the 10 to 12 leaf stage. It should be kept in mind that due to available labor, hand thinning is sometimes accomplished when beets have grown beyond the 10 to 12 leaf stage. It was felt that the 10 to 12 leaf stage would strike a happy medium and it would, therefore, be a fair treatment to use as the check to be representative of commercial practice. A little explanation is desirable on cross-thinning and cross-blocking. Cross-thinning is the term used to imply mechanical work to the final stand while cross-blocking infers leaving a mechanically treated stand which is in excess of that ultimately desired, then trimming out excess plants by long-handled hoe.

Each of the previously listed treatments was made on three seeding rates—3 to 4 seeds per foot, 7 to 8 seeds per foot, and 10 to 12 seeds per foot. Probably the 7 to 8 seeds per foot rate most nearly represents the average of commercial seeding rates.

Plots were replicated six times and tests were conducted in six different areas by five different sugar companies. The locations and companies responsible for the tests are:

1. Twin Falls, Idaho—Amalgamated Sugar Company
2. Saginaw, Michigan—Farmers & Manufacturers Beet Sugar Association
3. Longmont, Colorado—Great Western Sugar Company
4. Rocky Ford, Colorado—American Crystal Sugar Company
5. Idaho Falls, Idaho—Utah-Idaho Sugar Company
6. Salt Lake City, Utah—Utah-Idaho Sugar Company.

A test at Rocky Ford, Colorado, had to be discarded because small areas were later discovered to be affected by nematodes. In another test near Saginaw, Michigan, due to extreme unfavorable spring conditions, only one seeding rate was found possible.

The individual test results are shown, giving the location of each, in tables 1 to 5. Summaries have been computed for "Tons Per Acre," "Percent Sucrose," "After Thinning Stand Counts" and "Time Per Acre." Table 6 shows a combined summary of the tests where all three seeding rates were used (tables 1, 3, 4, 5).

## Discussion and Summary

If we are to maintain a balance in the mechanization of the sugar beet industry, spring labor requirements must be brought in line with fall labor requirements as rapidly as possible. Mechanical thinning tests conducted through The Foundation during the past two seasons demonstrate that this objective can be obtained.

General summary statements from the tests are:

1. The average yield in tons of beets per acre is increased as the seeding rate is increased. This is true for all treatments and becomes an important factor in the mechanical treatments.

**Table 1.—Mechanical Thinning Test, 1947, Twin Falls, Idaho.**

| Treatment | Tons per acre Seeding rate | | | | % sucrose Seeding rate | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-4 | 7-8 | 10-12 | Average | 3-4 | 7-8 | 10-12 | Average |
| Hand | 16.40 | 16.86 | 20.07 | 17.77 | 17.2 | 17.1 | 17.1 | 17.16 |
| Hoe | 16.07 | 18.39 | 19.40 | 17.95 | 17.3 | 17.0 | 17.0 | 17.10 |
| *C. T. 8" | 14.36 | 16.42 | 15.22 | 15.33 | 17.2 | 17.4 | 17.4 | 17.33 |
| **C. B. 8" | 14.74 | 17.16 | 17.85 | 16.58 | 17.3 | 17.3 | 17.1 | 17.23 |
| *C. T. 12" | 15.62 | 18.31 | 16.64 | 16.86 | 17.0 | 17.1 | 17.4 | 17.16 |
| **C. B. 12" | 14.07 | 15.60 | 17.38 | 15.58 | 17.3 | 17.1 | 17.5 | 17.30 |
| *C. T. 16-14" | 13.48 | 15.77 | 16.71 | 15.32 | 17.2 | 17.2 | 17.6 | 17.33 |
| ***Other | 14.42 | 15.85 | 17.13 | 15.80 | 17.2 | 17.3 | 17.6 | 17.36 |
| Average | 14.90 | 16.75 | 17.55 | 16.41 | 17.21 | 17.19 | 17.34 | 17.25 |

| Treatment | After-thinning stand-count Number beets per 100 feet Seeding rate | | | | Time per acre (hours) Seeding rate | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-4 | 7-8 | 10-12 | Average | 3-4 | 7-8 | 10-12 | Average |
| Hand | 76 | 61 | 94 | 77 | 23.6 | 26.6 | 29.7 | 26.63 |
| Hoe | 72 | 88 | 99 | 86 | 20.9 | 23.8 | 32.3 | 25.67 |
| *C. T. 8" | 99 | 115 | 139 | 118 | 15.3 | 17.0 | 20.9 | 17.73 |
| **C. B. 8" | 72 | 67 | 82 | 74 | 21.1 | 22.1 | 24.5 | 22.57 |
| *C. T. 12" | 96 | 130 | 114 | 113 | 15.3 | 17.0 | 20.9 | 17.73 |
| **C. B. 12" | 60 | 78 | 69 | 69 | 18.7 | 24.8 | 25.4 | 22.97 |
| *C. T. 16-14 | 104 | 120 | 122 | 115 | 15.3 | 17.0 | 20.9 | 17.73 |
| ***Other | 122 | 106 | 166 | 131 | 15.3 | 17.0 | 20.9 | 17.73 |
| Average | 88 | 96 | 111 | 98 | 18.19 | 20.66 | 24.44 | 21.10 |

*Cross-thinning.
**Cross-blocking.
***Twin Falls Weeder.

**Table 2.—Mechanical Thinning Test, 1947, Saginaw, Michigan. 10-12 Seeding Rate**

| Treatment | Tons per acre | % sucrose | After-thinning stand-counts—beets per 100' | Time per acre (hours) |
|---|---|---|---|---|
| Hand | 11.43 | 15.58 | 97 | 18.53 |
| Hoe | 11.49 | 15.60 | 106 | 18.30 |
| *C. T. 8" | 10.52 | 15.80 | 93 | 13.96 |
| **C. B. 8" | 10.23 | 15.45 | 72 | 12.58 |
| *C. T. 12" | 10.89 | 15.35 | 91 | 16.24 |
| **C. B. 12" | 10.62 | 15.58 | 102 | 16.47 |
| *C. T. 16" | 8.23 | 14.38 | 52 | 12.13 |
| ***Other | 10.74 | 15.68 | 97 | 13.27 |
| Average | 10.52 | 15.43 | 89 | 15.19 |

*Cross-thinning followed by weeder trimming.
**Cross-blocking and hoe trimming.
***Dixie followed by weeder trimming.

**Table 3.** Mechanical Thinning Test, 1947, Idaho Falls, Idaho.

| Treatment | Tons per acre Seeding rate | | | | % sucrose Seeding rate | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-4 | 7-8 | 10-12 | Average | 3-4 | 7-8 | 10-12 | Average |
| Hand | 21.26 | 22.22 | 21.19 | 21.56 | 17.74 | 17.82 | 17.94 | 17.83 |
| Hoe | 20.51 | 21.38 | 20.75 | 20.90 | 18.00 | 17.80 | 17.60 | 17.80 |
| *C. T. 8" | 19.64 | 20.00 | 19.59 | 19.74 | 17.90 | 17.70 | 17.76 | 17.78 |
| **C. B. 8" | 20.07 | 19.67 | 20.49 | 20.08 | 17.34 | 17.57 | 17.72 | 17.54 |
| *C. T. 12" | 17.69 | 19.59 | 19.62 | 18.96 | 17.62 | 17.86 | 18.02 | 17.83 |
| **C. B. 12" | 18.75 | 20.00 | 19.85 | 19.53 | 17.43 | 17.77 | 17.77 | 17.66 |
| *C. T. 16-14" | 19.35 | 19.31 | 20.76 | 19.80 | 17.39 | 17.87 | 17.79 | 17.68 |
| ***Other | 19.25 | 19.12 | 20.01 | 19.46 | 17.59 | 17.63 | 17.41 | 17.54 |
| Average | 19.57 | 20.16 | 20.28 | 20.00 | 17.63 | 17.75 | 17.75 | 17.71 |

| Treatment | After-thinning stand-count: Number beets per 100 feet Seeding rate | | | | Time per acre (hours): Seeding rate | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-4 | 7-8 | 10-12 | Average | 3-4 | 7-8 | 10-12 | Average |
| Hand | 87 | 96 | 100 | 94 | 18.00 | 20.60 | 22.50 | 20.37 |
| Hoe | 90 | 110 | 125 | 108 | 17.70 | 20.20 | 20.50 | 19.47 |
| *C. T. 8" | 101 | 114 | 119 | 111 | 6.50 | 6.60 | 7.80 | 7.00 |
| **C. B. 8" | 90 | 99 | 111 | 100 | 11.70 | 12.30 | 13.80 | 12.60 |
| *C. T. 12" | 82 | 122 | 123 | 109 | 6.90 | 6.70 | 6.20 | 6.60 |
| **C. B. 12" | 77 | 90 | 97 | 88 | 10.80 | 11.10 | 11.70 | 11.20 |
| *C. T. 16-14" | 88 | 108 | 131 | 109 | 6.20 | 6.20 | 5.90 | 6.10 |
| ***Other | 73 | 78 | 96 | 82 | 11.10 | 12.00 | 11.70 | 11.60 |
| Average | 86 | 102 | 113 | 100 | 11.11 | 11.96 | 12.51 | 11.87 |

*Cross-thinning.
**Cross-blocking then hoe trimming.
***Cross-blocking with 16-14" centers then hoe trimming.

**Table 4.** Mechanical Thinning Test, 1947, Salt Lake City, Utah.

| Treatment | Tons per acre Seeding rate | | | | % sucrose Seeding rate | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-4 | 7-8 | 10-12 | Average | 3-4 | 7-8 | 10-12 | Average |
| Hand | 28.80 | 30.15 | 30.86 | 29.94 | 15.22 | 15.66 | 16.09 | 15.66 |
| Hoe | 28.63 | 29.86 | 30.79 | 29.76 | 15.71 | 15.93 | 15.65 | 15.76 |
| *C. T. 8" | 25.93 | 27.49 | 29.39 | 27.60 | 15.22 | 15.31 | 15.44 | 15.32 |
| **C. B. 8" | 28.34 | 27.98 | 30.08 | 28.80 | 14.85 | 15.50 | 15.13 | 15.16 |
| *C. T. 12" | 27.07 | 26.91 | 31.13 | 28.37 | 15.48 | 15.33 | 15.38 | 15.40 |
| **C. B. 12" | 27.00 | 28.01 | 29.13 | 28.04 | 15.09 | 15.25 | 15.00 | 15.11 |
| *C. T. 16-14" | 26.60 | 28.50 | 30.05 | 28.40 | 14.78 | 15.14 | 15.35 | 15.09 |
| ***Other | 25.80 | 29.86 | 29.77 | 28.48 | 14.95 | 15.18 | 15.24 | 15.12 |
| Average | 27.27 | 28.60 | 30.15 | 28.67 | 15.16 | 15.41 | 15.41 | 15.33 |

| Treatment | After-thinning stand-count: Number beets per 100 feet Seeding rate | | | | Time per acre (hours): Seeding rate | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-4 | 7-8 | 10-12 | Average | 3-4 | 7-8 | 10-12 | Average |
| Hand | 83 | 99 | 106 | 96 | 19.82 | 23.31 | 25.63 | 22.92 |
| Hoe | 87 | 101 | 115 | 101 | 12.20 | 14.30 | 16.32 | 14.27 |
| *C. T. 8" | 79 | 77 | 97 | 84 | 10.26 | 6.84 | 6.37 | 7.82 |
| **C. B. 8" | 69 | 70 | 81 | 73 | 9.95 | 11.66 | 11.19 | 10.93 |
| *C. T. 12" | 78 | 78 | 87 | 81 | 9.95 | 9.01 | 5.13 | 8.03 |
| **C. B. 12" | 70 | 72 | 76 | 73 | 11.03 | 12.74 | 14.15 | 12.64 |
| *C. T. 16-14" | 75 | 85 | 91 | 84 | 9.32 | 6.06 | 8.39 | 7.92 |
| ***Other | 62 | 69 | 73 | 68 | 11.03 | 12.28 | 13.67 | 12.33 |
| Average | 75 | 81 | 91 | 83 | 11.70 | 12.03 | 12.61 | 12.11 |

*Cross-thinning.
**Cross-blocking then hoe trimming.
***Cross-blocking with 16-14" centers then hoe trimming.

**Table 5.—Mechanical Thinning Test, 1947, Longmont, Colorado.**

| Treatment | Tons per acre Seeding rate 3-4 | 7-8 | 10-12 | Average | % sucrose Seeding rate 3-4 | 7-8 | 10-12 | Average |
|---|---|---|---|---|---|---|---|---|
| Hand | 12.26 | 12.33 | 13.72 | 12.77 | 11.9 | 12.8 | 13.0 | 12.57 |
| Hoe | 12.70 | 12.49 | 12.23 | 12.47 | 12.6 | 12.9 | 13.2 | 12.90 |
| *C. T. 8" | 11.98 | 11.77 | 11.17 | 11.64 | 12.8 | 13.0 | 12.3 | 12.70 |
| **C. B. 8" | 10.86 | 10.83 | 12.37 | 11.35 | 11.9 | 12.6 | 12.4 | 12.30 |
| *C. T. 12" | 10.79 | 11.70 | 11.27 | 11.25 | 12.5 | 12.7 | 12.5 | 12.57 |
| **C. B. 12" | 12.11 | 11.08 | 10.99 | 11.39 | 12.1 | 12.8 | 12.3 | 12.40 |
| *C. T. 16-14" | 10.72 | 11.38 | 11.12 | 11.07 | 12.8 | 12.7 | 12.2 | 12.57 |
| ***Other | 10.88 | 10.80 | 12.12 | 11.27 | 12.5 | 12.5 | 13.4 | 12.80 |
| Average | 11.54 | 11.55 | 11.87 | 11.65 | 12.39 | 12.75 | 12.66 | 12.59 |

| Treatment | After-thinning stand-count Number beets per 100 feet Seeding rate 3-4 | 7-8 | 10-12 | Average | Time per acre (hours) Seeding rate 3-4 | 7-8 | 10-12 | Average |
|---|---|---|---|---|---|---|---|---|
| Hand | 69 | 85 | 84 | 79 | 30.4 | 31.6 | 32.6 | 31.5 |
| Hoe | 83 | 97 | 100 | 93 | 25.5 | 27.1 | 27.8 | 26.8 |
| *C. T. 8" | 88 | 91 | 98 | 92 | 23.2 | 22.3 | 18.9 | 21.5 |
| **C. B. 8" | 75 | 82 | 90 | 82 | 26.3 | 22.5 | 19.5 | 22.8 |
| *C. T. 12" | 77 | 101 | 109 | 96 | 26.7 | 19.1 | 19.8 | 21.9 |
| **C. B. 12" | 84 | 93 | 83 | 87 | 26.6 | 22.6 | 24.3 | 24.5 |
| *C. T. 16-14" | 90 | 77 | 91 | 86 | 28.1 | 19.3 | 18.2 | 21.9 |
| ***Other | 80 | 93 | 109 | 94 | 27.0 | 24.1 | 22.4 | 24.5 |
| Average | 81 | 90 | 96 | 89 | 26.73 | 23.58 | 22.94 | 24.43 |

*Cross-thinning.
**Cross-blocking.
***Harrow.

**Table 6.—Mechanical Thinning Tests, 1947, Summary Averages.**
**(Based on 4 tests of 6 replications each)**

| Treatment | Tons per acre Seeding rate 3-4 | 7-8 | 10-12 | Average | % sucrose Seeding rate 3-4 | 7-8 | 10-12 | Average |
|---|---|---|---|---|---|---|---|---|
| Hand | 19.68 | 20.39 | 21.46 | 20.51 | 15.52 | 15.85 | 16.03 | 15.81 |
| Hoe | 19.49 | 20.53 | 20.79 | 20.27 | 15.90 | 15.91 | 15.86 | 15.89 |
| *C. T. 8" | 17.98 | 18.92 | 18.84 | 18.58 | 15.78 | 15.85 | 15.73 | 15.78 |
| **C. B. 8" | 18.50 | 18.91 | 20.20 | 19.20 | 15.35 | 15.74 | 15.59 | 15.56 |
| *C. T. 12" | 17.79 | 19.13 | 19.67 | 18.86 | 15.65 | 15.75 | 15.83 | 15.74 |
| **C. B. 12" | 17.98 | 18.67 | 19.34 | 18.66 | 15.48 | 15.73 | 15.64 | 15.62 |
| *C. T. 16-14" | 17.54 | 18.74 | 19.66 | 18.65 | 15.54 | 15.73 | 15.74 | 15.67 |
| Other | 17.59 | 18.91 | 19.76 | 18.75 | 15.56 | 15.65 | 15.91 | 15.71 |
| Average | 18.32 | 19.28 | 19.97 | 19.19 | 15.60 | 15.78 | 15.79 | 15.72 |

| Treatment | After-thinning stand-count Number beets per 100 feet Seeding rate 3-4 | 7-8 | 10-12 | Average | Time per acre (hours) Seeding rate 3-4 | 7-8 | 10-12 | Average |
|---|---|---|---|---|---|---|---|---|
| Hand | 79 | 85 | 96 | 87 | 22.96 | 25.53 | 27.61 | 25.36 |
| Hoe | 83 | 99 | 110 | 97 | 19.08 | 21.35 | 24.23 | 21.55 |
| *C. T. 8" | 92 | 99 | 113 | 101 | 13.82 | 13.19 | 13.49 | 13.51 |
| **C. B. 8" | 77 | 80 | 91 | 83 | 17.26 | 17.14 | 17.25 | 17.23 |
| *C. T. 12" | 83 | 108 | 108 | 100 | 14.71 | 12.95 | 13.01 | 13.57 |
| **C. B. 12" | 73 | 83 | 81 | 79 | 16.78 | 17.81 | 18.89 | 17.83 |
| *C. T. 16-14" | 89 | 98 | 109 | 99 | 14.73 | 12.14 | 13.35 | 13.41 |
| Other | 84 | 87 | 111 | 94 | 16.11 | 16.35 | 17.17 | 16.54 |
| Average | 83 | 92 | 102 | 93 | 16.93 | 17.06 | 18.13 | 17.38 |

*C. T.—Cross-thinning.
**C. B.—Cross-blocking.

2. Variation in block center has little or no effect on yield or labor requirement.

3. Based on these results growers should be cautioned on the real low rates of seeding as has been advocated in some sections. The long-handle hoe is increased by slightly more than 1 ton per acre as the seeding rate is increased from 3 to 4 seeds to 7 to 8 seeds per foot. This increased yield more than offsets the decreased labor requirement under the light seeding rate.

4. Except for the 8-inch centers, there is no advantage in cross-blocking over cross-thinning. It should likewise be kept in mind that labor required for cross-blocking exceeds that of cross-thinning by approximately 4 hours.

5. It appears that the heavier seeding rates are the best adapted to mechanical thinning. It should be noted that this seeding rate of 10 to 12 seeds per foot which approximates 5 to 6 pounds of seed per acre, in 20-inch row widths, is the seeding rate now recommended in the Red River Valley of Minnesota, where mechanical cross-blocking has been used commercially.

6. The reduction of labor requirement follows the same pattern as last year for mechanical work. Cross-thinning on 12-inch centers shows a time reduction of 46 percent over hand-block and thin in 1947 and 43 percent in 1946.

7. The seeding rate has a direct reflection on the distribution pattern left after thinning. As the seeding rate is increased the number of blocks containing no beets is decreased. The after-thinning plant distribution is reflected in yield per acre—the better the distribution, the higher the yield.

8. There is a relationship between time requirements and condition of field for hand thinning and hoe thinning. A field which is relatively free of weeds will show a greater saving in labor for hoe thinning over hand thinning than a more weedy field. Little reflection of field condition and time requirement is observed with the straight mechanical treatment, in either case time requirement is cut almost in half by the mechanical work. Where hoe trimming is required after cross-blocking, the more weedy fields again show greater time requirement.

9. Inasmuch as the 1947 tests have indicated that block centers are relatively unimportant, then the type of tool should be used for mechanical thinning which will give the maximum of weed elimination in conjunction with the removal of the excess beets.

10. The use of mechanical tools permits the job of thinning to be finished in a minimum of time. It also permits planting the entire field at the earliest date possible rather than staggering the dates so as to make beets come up at different times, thereby fitting into the slower pattern of hand thinning. This practice of planting so as to have only a small acreage of beets ready for hand thinning at any given time is common

practice in some areas. Experiments generally show that the early planted beets outyield those planted at later dates.

11. Thinning time requirement is not altered materially as initial seeding rates are increased in the case of the cross-thinning treatments. With treatments requiring hoe trimming or all hand work, thinning time requirement increases as seeding rate increases.

12. It is logical to assume that cross-thinning will affect a greater weed reduction than cross-blocking minus the hand trim. This is of importance inasmuch as the method which has the greatest saving in labor likewise has the greatest possibility at weed reduction and yet does not reduce the final yield of sugar beets.

13. Generally, after-thinning stand-counts for cross-thinning treatments exceed the counts for cross-blocking treatments by 20 beets for each 100 feet of row. A logical assumption is that the cross-thinning treatments would leave a larger number of two or more beet-containing blocks. This assumption is confirmed by a careful analysis of the after-thinning stand-counts (detailed data which is not published in this report). It is apparent, therefore, that a limited number of double and multiple hills will not impair the final yield.

14. Sufficient work on spring mechanization has now been done to point out the main possibilities and procedures. The main job now facing the industry appears to be one of education and salesmanship.

# Stands Resulting From Low-Seeding Rates Of Decorticated Seed With a Precision Planter

R. J. TINGLEY[1]

A PRACTICAL TEST PLANTING on a field basis, using four different low-seeding rates to determine the field emergence and resulting stands, was made in Fresno County, California, in October 1947. A John Deere No. 66 precision planter was used to plant at rates of approximately 4, 6, 8 and 10 seeds per foot of row.

Because of the location and date of planting, a bolting-resistant variety, U.S. 56, was used. The actual laboratory germination of the only lot of this seed available was rather low for this kind of trial, but generally satisfactory stands were obtained in all treatments. The seed was decorticated and sized through 9/64-inch and over 7/64-inch round-hole screens. The complete germination and planting data are shown in table 1.

Table 1. Germination—U.S. 56 seed.

| Percent | | | | | Seedlings per 100 seeds | Seedlings V. U. | Seeds per pound |
|---|---|---|---|---|---|---|---|
| Normal | Abnormal | S | D | T | | | |
| 73.0 | 4.5 | 41.5 | 29.0 | 2.5 | 107 | 1.46 | 54,650 |

**Results of Field Planting**

| Treatment | Pounds seed per acre | Seeds per foot | Seeds per 100 inches | Potential seedlings per 100 inches |
|---|---|---|---|---|
| A | 1.375 | 4.31 | 35.92 | 38.45 |
| B | 1.938 | 6.08 | 50.62 | 54.20 |
| C | 2.500 | 7.84 | 65.35 | 69.90 |
| D | 3.125 | 9.81 | 81.72 | 87.40 |

The plots consisted of 4 rows 1,750 feet in length. The plantings were on single-row beds, spaced 30 inches apart. Each rate of seeding was replicated five times, randomized in one block of a 100-acre field. The four rates of seeding were designated as follows: Treatment A, 4 seeds per foot; Treatment B, 6 seeds per foot; Treatment C, 8 seeds per foot; and Treatment D, 10 seeds per foot. These desired spacings, and the actual corresponding pounds of seed used per acre, were secured by using the following gear ratios:

| | | |
|---|---|---|
| Treatment A | 7 to 8 | 1.375 pounds per acre; |
| Treatment B | 12 to 9 | 1.938 pounds per acre; |
| Treatment C | 12 to 7 | 2.500 pounds per acre; |
| Treatment D | 18 to 8 | 3.125 pounds per acre. |

[1]District Agriculturist, Holly Sugar Corporation.

The planting was made at an average of 2.84 miles per hour and a planter efficiency performance of 98.4 percent. The seed was planted approximately ¾-inch deep in dry ground. The plots were all irrigated within 4 or 5 days after planting, and as is generally practiced on the farm, some anhydrous ammonia fertilizer was added to the first irrigation water. Ground and air temperatures were low throughout the germination and emergence period and the development was slow, but the overall field emergence was relatively high.

The actual planting results as shown in table 1 indicate spacing of seed very close to that originally planned.

A total of five standard 100-inch counts were made in each replicate of all treatments and the average results for each treatment are shown in table 2.

**Table 2.—Germination Stand.**

| Treatment | Plant inches | Inches With | | | Total plants | Percent singles | Percent emergence |
|---|---|---|---|---|---|---|---|
| | | S | D | T | | | |
| A | 15.9 | 12.4 | 2.9 | 0.6 | 19.9 | 78.0 | 52.0 |
| B | 21.0 | 14.2 | 5.6 | 1.2 | 29.7 | 67.6 | 55.2 |
| C | 26.7 | 16.8 | 7.9 | 2.0 | 39.4 | 62.9 | 57.1 |
| D | 33.1 | 19.3 | 10.1 | 3.7 | 52.2 | 58.3 | 59.6 |

## General Statistical Analyses

As is generally the case, the percentage of singles decreased with the increase in the seeding rate. The increase in the percentage of emergence with higher rates of seeding is difficult to explain since in no case were there enough plants coming through the ground to affect, or help, emergence of adjacent plants. Since the ground speed of the drill was controlled to 2.84 miles per hour for all seeding rates the only variable was the rate of plate travel which increased with each progressive gear change. It is possible that excessive cell fill and attendant seed damage decreased with higher seeding rates, accounting for some increased emergence.

It was planned that thinning would have been completed before the time of this meeting and that a report on time studies to determine the man-hours per acre required to thin all plots to the desired stand of 150 beets per 100 feet of row would be made. Frequent frosts and low mean temperatures have delayed the crop development and thinning has been delayed so that such studies cannot now be made until about the end of January.

This field trial indicates that it is entirely possible to secure good stands of beets from very light rates of seeding, as low as 4 seeds per foot, where improved, processed seed is planted with a precision drill in a well-prepared seedbed.

High field emergence of uniform stands may be expected from very light-seeding rates of decorticated seed, by planting in dry beds with a good precision drill and following with irrigation.

# Red River Valley Experience in Mechanizing Sugar Beet Growing and Harvesting Operations, 1947 Season

O. A. Holkesvig[1]

Growers in the Red River Valley started cross-cultivation of beets in 1930, which resulted in such an increase in labor efficiency in thinning that it became the universal practice.

With the introduction of segmented seed and equipment for more precise placement of drilling seed, some 450 acres of beets were not thinned in 1946 with such satisfactory results that, had there been a harvester available to top beets in blocks containing multiples, a large acreage would have been handled in this way in 1947.

Fortunately, the Sterling Machine Company of Minneapolis, asked us to cooperate with them in final field testing with their Harvall Beet Combine which lifts, tops and loads two rows in one operation. Tests which we ran with this machine in 1946, had demonstrated its ability to properly top multiple beets in non-thinned fields.

In preparation for a field test in 1947, 30.5 acres were planted on company land. This field was planted to sweetclover with barley as a nurse crop, in 1945. In 1946, when the sweetclover reached a growth of 2 feet, it was plowed under, then disced and tilled with a field cultivator at regular intervals for the balance of the season. The land was leveled with an Eversman land leveler twice, before final ridging with a field cultivator, to prevent winter wind erosion just before the ground froze in the fall of 1946. The field was planted May 21 with a John Deere No. 66 twelve-row planter, at the rate of 5 pounds of segmented seed per acre at a 2-mile per hour drill speed.

One-hundred-inch stand-counts showed 19.86 inches containing singles; 7.26 inches containing doubles, and 1.13 inches containing 3 or more plants per inch, or a total of 28.25 beet-containing inches. Rows were spaced on 18-inch centers and for the cross-pattern, the cultivator was set to space three 16-inch rows, and five 14-inch rows, leaving 1½-inch blocks at right angles to the drill rows. This pattern provided 23,626 blocks per acre. After crossing, 600 block counts were made as follows:

233 blocks were blank; 191 contained singles; 133 contained doubles; and 43 contained 3 or more, or a total of 14,452 beet-containing blocks per acre—a population of 23,078 plants per acre. This field was cultivated three times down the row with a pencil weeder attached to the rear bar of

[1]Manager, Red River Valley area, American Crystal Sugar Co.

the cultivator for one cultivation and was cross-cultivated three times with the pencil weeder attached to the rear bar of the cultivator for one cultivation.

Labor which performed the hoeing, kept their own time and were paid 75 cents per hour. It took them 94 hours to hoe, at a cost of $2.31 per acre.

This field yielded 10.07 tons per acre, which was approximately 1 ton more per acre than the average yield of the hand-thinned acreage for the area this year.

I am sure you are interested in knowing the total man hours required to produce this non-thinned crop from seedbed preparation to loading into truck:

| | Man hours per acre |
|---|---|
| Seedbed preparation | .75 |
| Planting with 12-row planter | .28 |
| Cultivation, six times | 2.29 |
| | 3.32 |
| Pulling weeds | 3.07 |
| Harvall harvesting | 2.00 |
| Total | 8.39 |

The field was harvested with a Harvall harvester at a cost of:

| | |
|---|---|
| 30.5 hours for 2 men @ $1.00 per hour for each man | $ 61.00 |
| Fuel and oil, $1.00 per acre, 30.5 acres | 30.50 |
| Cost of vine beater per acre, 30.5 acres @ $3.00 | 91.50 |
| Actual cost of operating, only | $183.00 |
| **Cost of hoeing:** | |
| 30.5 acres @ $2.31 per acre | 70.45 |
| | $253.45 |

Cost if old method had been employed:

| | Per acre | Total cost |
|---|---|---|
| Thinning and hoeing cross-cultivated | $ 16.50 | $ 503.25 |
| Labor procurement | 3.00 | 91.50 |
| Pulling beets, floating and trimming windrow | 3.21 | 97.91 |
| Hand harvest, 10.07 tons @ $1.75 | 17.62 | 537.41 |
| Loading beets | 3.50 | 106.75 |
| Return transportation for labor | 3.00 | 91.50 |
| | $ 46.83 | $1,428.32 |

**Cost Comparisons**

| | 30.5 acres, total cost | 307.25 tons, cost per acre | Average yield—10.07 tons, cost per ton |
|---|---|---|---|
| Old method | $1,428.32 | $46.85 | $4.65 |
| Mechanized method | 253.45 | 8.31 | .83 |
| Savings made | $1,174.87 | $38.54 | $3.82 |

The above figures do not include costs for depreciation, maintenance, and interest on investment of any machinery used.

# A Press-Wheel Study To Improve Beet Seedling Emergence

R. D. Barmington[1]

The success of spring mechanization depends to a large extent upon the germination of a high percentage of the seed pieces placed in the soil and the emergence of a uniform stand of beet seedlings. With precision planting and reduced seeding rates all irregularities in field emergence are much more apparent than they were when heavy-seeding rates were used. Under ideal germinating conditions and with precision planters now available it would be quite possible to plant to a final stand eliminating entirely the necessity for any kind of thinning. If it were possible to produce ideal germinating conditions in the field, or to recognize the proper combination of equipment necessary, the problem of getting good emergence would be greatly simplified. Assuming that the essential elements necessary to produce a germinating condition are fairly well understood, the mechanics of producing optimum results under a variety of field conditions will require a great deal more study and experimentation.

To obtain as much information as possible on both the field conditions and the combinations of planter equipment necessary, the Colorado Agricultural Experiment Station, The U. S. Department of Agriculture, and the Beet Sugar Development Foundation have cooperated on some rather large-scale tests. In 1946, plantings with 8 types of press wheels were made in 8 different fields over a territory 600 miles wide in the Rocky Mountain area. In 1947, twenty-four different combinations of press wheels and other devices were used at only one location but with two plantings, on May 22 and August 8.

Weather conditions at planting time throughout the Rocky Mountain area in 1946 were universally dry. Seedbeds varied from fine-textured surfaces to cloddy; and from light sandy soils to heavy clay loam. In all cases the surface soil was too dry to germinate seed for a depth of from 1½ to 3 inches with plenty of moisture in the subsoil below. The earliest planting was made March 20 in dry surface soil and remained in dry soil for 5 weeks without rain or irrigation. Some plantings were made after rains had fallen, but the surface moisture was lost due to the necessity of working the field to kill weeds before planting. Without exception, the 1946 experiments were planted in dry soil which remained dry from a few days to 5 weeks after planting.

In 1947, the press-wheel test was planted at Fort Collins on May 22 in a moist firm seedbed and on May 23 a heavy rain fell on the plots. For the summer planting on August 8, the field was irrigated before planting

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and again after planting to overcome some of the effects of the hot weather. This planting was to serve the dual purpose of a press-wheel study and to provide beets of a proper size for thinning demonstrations at a later date.

Examination of table 1 will show that some of the devices which showed greatest promise in 1946 are at the bottom of the list in 1947. At first this seems to be very confusing and some early predictions had to be rescinded. Close analysis of all the facts will show that the principles involved are not at fault, but that the mechanical means of obtaining the desired soil and seed relationship must be different for different field conditions. To produce a germinating condition there must be a firm contact between the seed and moist soil surrounding the seed. In 1946, the dry surface soil responded to one type of mechanical equipment while the moist soil in 1947 required a different treatment to produce a firm soil around the seed.

**Table 1.**—Press-wheel emergence study.

| Treatment | 1947 Percentage comparison combining May and August plantings. Check = 100 | 1946 Percentage comparison of six replicated tests. Check = 100 |
|---|---|---|
| 1. Olsen-Beck with 3/4" protruding sprockets (2 sprockets each 1/4" thick) | 136 | --- |
| 2. Blunt sprocket with flat press wheels—teeth 3/4" deep with the diameter of the root circle lying 3/8" above the surface of the press wheels | 123 | --- |
| 3. Wedge press wheels—10" diameter—1 1/2" thick—22 1/2° included angle | 123 | 115 |
| 4. Sharp sprocket between deep concave press wheels—teeth 3/4" deep with the diameter of the root circle lying 3/16" below the inside edge of the press wheel | 118 | --- |
| 5. 10" x 1 1/2" double-rubber press wheels | 118 | 117 |
| 6. 16" x 3 1/2" single-rubber press wheel with light chain dragged behind | 116 | --- |
| 7. 3" diameter press wheel in front of opener with standard press wheel behind | 115 | 135 |
| 8. Olsen-Beck with two 3/16" thick sprockets between press wheels—outside diameter of sprocket flush with surface of press wheel | 115 | --- |
| 9. Blunt sprocket between standard press wheels—root diameter flush with inside edge of press wheel | 114 | --- |
| 10. English press wheel—5" wide | 114 | --- |
| 11. 10" x 1 3/4" single-rubber press wheel with chain dragged behind | 113 | --- |
| 12. English press wheel with smoother between discs (smoother failed and was removed) | 110 | --- |
| 13. 1 1/4" deep furrow firmer in front of opener with standard press wheels behind) | 108 | --- |
| 14. Smoother between discs with standard concave press wheels | 108 | --- |
| 15. Plain flat press wheels—9" diameter | 106 | 134 |
| 16. 14" Sishc press wheel (3 abreast)—1 1/2" apart—teeth 1 1/4" deep | 101 | --- |
| 17. Standard check. Plain deep concave press wheel (John Deere) | 100 | 100 |
| 18. Cast iron beveled face press wheel. I.H.C. | 94 | --- |
| 19. 10" x 1 1/2" flat steel press wheel with scraper (Bakersfield type) | 92 | --- |
| 20. 10" x 1 1/2" flat steel wheel with scraper removed | 89 | --- |
| 21. 18" diameter Sishc wheel arranged 2 in front and 1 behind | 82 | 154 |
| 22. 14" diameter Sishc wheel arranged 2 in front and 1 behind | 80 | --- |
| 23. Standard concave press wheels reversed—spaced 3/4" apart | * | --- |
| 24. 16" x 3 1/2" single-rubber press wheel with scraper in front, dragging chain behind | * | --- |
| 25. Western land roller wheels | Not tested | 109 |
| 26. Standard I.H.C. press wheels | Not tested | 125 |

*August planting only. Significantly better than the check.
Difference required for significance at the 5 percent level (19:1 odds) for 1947 = 12.5.
Difference required for significance at the 5 percent level (19:1 odds) for 1946 = 18.5.

The 18-inch Sishc press-wheel unit consisting of 5 sprocket-like wheels and weighing 165 pounds per unit gave consistently higher emergence in the dry seedbeds where there was insufficient surface moisture for immediate germination. The same arrangement used with abundant surface moisture was disappointing. The projections on the rim of the wheels packed the moist soil around the seed as the projections came down, but as the wheel rolled forward the moist soil stuck to the teeth and loosened the seedbed as they came up. Other types of press wheels such as the two 10-inch x 1½-inch rubber wheels and the 10-inch x 1½-inch wedge wheels were not significantly better than the check under the dry-soil condition, but they were significantly better when the soil was moist.

The first 11 treatments listed in table 1 were significantly better than the check in 1947, with treatment 12 about on the border line of significance. Treatments 23 and 24 were replicated, but at only one planting date, August 8, and in this one test they were found to be significantly better than the check plot. Treatments 21 and 22 were definitely poorer than the check in 1947 and number 19 was about on the border line of significance.

In the 1946 test the standard press wheels which were used as the check method was at the bottom of the list from the standpoint of emergence. The large Sishc press-wheel arrangement, the plain flat-press wheels 9 inches in diameter and the small press wheel in front of the opener were all decidedly better than the check. The Western Land Roller wheels, used as press wheels, the wedge press wheels, and the double-rubber press wheels did not show a significant improvement. For some reason the standard International press wheel showed considerable improvement over the standard John Deere wheels and they are very nearly the same size and shape.

The most consistent improvement was shown in 1947 by the addition of some kind of toothed projections between the two halves of the conventional type of press wheel with both the deep concave and relatively flat wheels. The length of the projection beyond the rim of the wheel evidently made some difference, but it would seem quite possible that if the projections were extended too far the same kind of action might be encountered as with the Sishc wheel. With the equipment used, the two parts of the conventional press wheel acted as a depth gage for the various toothed wheels. This type of equipment was not included in the 1946 test so the data cannot be taken as conclusive, however, the first year's results are encouraging enough to warrant further investigation of this type of equipment.

One other type of press wheel, which looked very good in the field, was a copy of an English planter. This was made of two circular steel plates 12 inches in diameter and 5 inches wide with heavy bicycle-wheel spokes running between the two plates forming a squirrel-cage arrangement. Inside the cage and rolling freely on the inside of the bicycle spokes was a piece of triple-strength tubing with a diameter a little less than half

the diameter of the side plates. The differences with this device were significant and the action in the soil was very good. More tests should be made with it.

With only 1 or 2 years' data on the various types of equipment it would be dangerous to try to make any predictions or to draw any definite conclusions. One thing which seems to be evident in both tests is that the deep concave press wheel, which is standard equipment on some planters, is not as good as some of the other types of press wheels. Anything that can be done to increase the unit pressure on the soil in the immediate vicinity of the seed is good if the device does not tear up the seedbed as it moves on down the row. In general, a device which leaves a rough surface directly over the row, stands a better chance of preventing crust formation than one which leaves a smooth packed surface or glazed surface. Any device or combination which will leave the seed encased in firmly packed moist soil in any field condition would, of course, be the ultimate goal in planter design. It will be necessary to repeat tests of the devices now available over a number of years, adding any new ideas that come up until some definite trend is established, before any recommendations can be made.

The factors influencing field results are many and varied. Among these factors are soil moisture, the amount of humus in the soil, size of soil particles which may vary from dust to clods an inch or more in diameter, temperature of the soil, and many others. Continued investigation of equipment design and field conditions will surely reveal at least a partial solution to the emergence problem.

Any improvement in general cultural practice will do a great deal to improve seedling emergence and to advance spring mechanization in general. Greater benefits from light-seeding rates could be realized now if it were not for the weed-control problem. With perfect weed control the time will come when beets will be planted to a final stand like other farm crops and no hand work will be required for thinning

# Improvement of Sugar Beet Seedling Emergence by Planter Development

S. W. McBirney[1]

IMPROVEMENT of the percentage and uniformity of sugar beet seedling emergence in the field is at present one of the most important needs in mechanization of spring operations in sugar beet production. As long as the percentage of potential emergence on commercial plantings continues to vary from 10 to 60 percent, sometimes even outside that range, it is impossible to approach planting to a stand and it is hazardous to reduce seeding rates to the point where very little thinning is needed. Furthermore, as long as the percentage of emergence varies 200 or 300 percent on different parts of a field, as it occasionally does or even sometimes from count to count down a row, mechanical thinning with any equipment set-up is bound to give erratic and spotty field stands. The low percentage, or lack of uniformity of emergence, may result from several causes, including seedbed fitting, planter, planting job, seed, seedbed moisture, insect damage, and others of which some at least are unknown.

One of the major objectives of the sugar beet machinery project of the United States Department of Agriculture, during the last 2 or 3 years, has been the development of planters to improve the percentage and uniformity of seedling emergence. This project is cooperative with the Colorado and Michigan Agricultural Experiment Stations, but the information on only the seedling emergence work at the Colorado Station at Fort Collins is included in this report. This research has also included a study of seedbed preparation to a limited extent, but is largely with planting equipment. The Colorado Station also has been cooperating with the Beet Sugar Development Foundation on beet machinery development and they too have been carrying on work to further investigate seedling emergence characteristics of planting equipment. The results of their work are being presented in a separate report.

Two sets of beet-planter study plots were put in at Fort Collins in 1947 in continuation of this phase of our project. They were planted on the College Agronomy Farm with the cooperation of the Division of Sugar Plant Investigations of the United States Department of Agriculture, particularly in the matters of seedbed preparation and carrying the crop through harvest. The plantings included one early in the season (mid-April) when seedbed moisture conditions were good and one late in the season (mid-June) when soil moisture was expected to be low and perhaps a limiting factor in seedling emergence.

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The first planting was started on April 14, but was interrupted when one fourth done by a snow storm of .13 inch precipitation on April 15. The planting was resumed on April 17 and replications of all treatments were put in. This planting was followed by several days of light rain every day or so with an accumulated precipitation by April 28 of .84 inch and traces of precipitation intermittently for the next 10 days. There was, therefore, plenty of moisture for seed germination without soil crusts forming. The seedling emergence was very good. It averaged 75 percent for the check planting.

The second planting was delayed until June 17 in order to get a seedbed somewhat on the dry side. However, this planting was followed by rains as follows: .50 inch on the night of June 17, .08 inch on the 18th, .97 inch on the 20th to 22nd, traces on the 24th and 26th and .11 inch on the 29th. There was, therefore, plenty of moisture for germination. Moderate soil crusts were formed during that period by the rain and soil drying which were mechanically broken with small rotary-hoe-type units on June 20 and 24 before the rain fell. Seedling emergence was good in spite of soil crusts and some losses from crust breaking because the check planting averaged 47 percent.

The equipment used consisted of thirty different modifications or combinations of the furrow opener or press wheels. Most of them were used mounted on a John Deere No. 55 beet-planter chassis equipped with the new No. 64 planter seed plates and cut-offs. Special false plates and 5/8-inch O.D. by 17/32-inch I.D., smooth, slightly curved seed tubes leading below the opener-disk centers were used. Pressed-steel seed plates of .128-inch thickness and with .168-inch diameter seed cells were used. The seed was 7/64- to 10/64-inch, segmented, American Crystal Sugar Company variety No. 3 and had a germination percentage of 81 with 1.59 sprouts per viable segment. The seeding rates used were 3.16 pounds per acre for the first planting and 1.85 pounds per acre for the second. The planter drives used gave 2.83 inches per cell or 4.25 cells per foot on the first planting and 4.91 inches per cell or 2.45 cells per foot for the second.

The measure of effectiveness of each opener set-up was the percentage of potential seedling emergence obtained with that set-up. Twenty 100-inch seedling stand-counts were taken on replicated plots for each set-up. The average stand was reduced to a percentage of the potential emergence determined from the seeding rate, the seed segments per pound, and the sprouts per hundred segments. The percentages of emergence for all set-ups are directly comparable.

One of the most striking results of the tests is the importance indicated for depth of planting on seedling emergence. This is not new information and merely confirms data obtained last year on similar tests. In fact, every sugar company fieldman is aware of the influence of planting depth on emergence. However, I think many of us have taken this matter too much for granted and have been more or less ignoring it.

Plantings were put in on both early and late plantings with regular double-disk openers with the depth bands set for 1-, 1½-, and 2-inch planting depths. Bevel-rim press wheels set about ¾ inch apart were used on the openers. The results, shown in table 1, show that the shallower, 1-inch, planting is the best for the early plantings where there is usually plenty of moisture, because the soil is colder and germination is slower. The difference between 1- and 1½-inch depths is not quite significant, but last year was very significant as the 1-inch was 50.3 percent and the 1½-inch was 40.4 percent with 5.2 percent needed for significance. For the later planting the 1½-inch depth was significantly better than for the 1-inch and this was equally true last year when the averages showed 20.9 and 35.0 percents for 1- and 1½-inch depths respectively. For these later plantings, moisture may be limited at the 1-inch depth. As the soil is warmer, the 1½-inch depth seed germinates better.

**Table 1.**—Effect of planting depth on seedling emergence.

| Depth of Planting | Percentage seedling emergence | |
|---|---|---|
| | Planted 4/17/47 | Planted 6/17/47 |
| 1 inch | 75.15 | 34.75 |
| 1½ inches | 70.05 | 46.95 |
| 2 inches | 65.80 | 43.10 |
| Difference for significance (5% level) | 8.50 | 9.57 |

Many beet growers have a habit of using one planter set-up for all of their plantings. If the planter has depth bands on the disk openers set for 1½-inch depth of planting, it is likely to be used that way even if the planting is being done in late March or early April. I believe the average percentage of seedling emergence in nearly every district can be improved if the growers are impressed with the advantage of setting the planter for the desired planting depth. It is quite a job to change a set of the old-type depth bands to give a different planting depth, but with the new pressed-steel depth bands, such as are being used by John Deere or International, the change can be made in a few minutes. In most cases a lower seeding rate can be used to get the desired stand.

The seedling-emergence data for the different equipment tested to investigate this planter characteristic and the differences needed for statistical significance are shown in table 2. The planting depth used for all the equipment was 1 inch on April 17 and 1½ inches on June 17, based on the previous years' tests at different planting depths and dates. All of the openers and press wheels were John Deere equipment unless otherwise noted. The disk openers were all of the double-disk type. The press wheels were of the flat, bevel-rim type and both bevel-rim and deep-concavity types were used with about ¾-inch space between the wheels unless otherwise noted. Other manufacturers build similar openers and press wheels.

Table 2.—Beet planter seedling emergence data.

| Line No. | Equipment used | Percent emergence | | |
|---|---|---|---|---|
| | | Planted 4/17/47 | Planted 6/17/47 | Average |
| 1 | Disk opener with bevel-rim press wheels | 75.2 | 47.0 | 61.1 |
| 2 | Disk opener with deep-concavity press wheels | 62.1 | 53.7 | 57.9 |
| 3 | Disk opener, deep concavity press wheels together | 77.3 | 45.8 | 61.5 |
| 4 | Disk opener, sprocket between concave press wheels | 81.4 | 58.4 | 69.9 |
| 5 | Disk opener with 2 cultipacker press wheels | 70.4 | 49.3 | 59.8 |
| 6 | Disk opener with 2 Sisbe press wheels | 42.6 | 50.7 | 46.6 |
| 7 | Disk opener with 2-1 Sisbe press wheels | 66.9 | 49.4 | 58.1 |
| 8 | Disk opener with 2 cultipacker and 2 Sisbe press wheels | 78.2 | 52.0 | 65.1 |
| 9 | Disk opener with 2 pairs sharp-edged press wheels | 64.1 | 42.9 | 53.5 |
| 10 | Disk opener with fertilizer boot normal position | 68.2 | 37.0 | 52.6 |
| 11 | Disk opener with fertilizer boot offset | 81.1 | 45.2 | 63.1 |
| 12 | Disk opener with scraper bar between disks | 62.2 | 44.4 | 53.3 |
| 13 | Disk opener with seed coverer between disks | 69.7 | 45.4 | 57.6 |
| 14 | Disk opener with bar and coverer between disks | 68.1 | 38.3 | 53.2 |
| 15 | Disk opener with runner type shoe between disks | 56.3 | 46.2 | 51.2 |
| 16 | Disk opener with shoe and coverer between disks | 70.9 | 34.7 | 52.8 |
| 17 | Disk opener with small shoe on seed tube | 70.5 | 43.6 | 57.0 |
| 18 | Disk opener with round bottom shoe between disks | 71.4 | 51.0 | 61.2 |
| 19 | Runner opener with bevel-rim press wheels | 69.3 | 52.7 | 61.0 |
| 20 | Runner opener with concave wheels together | 70.8 | 49.7 | 60.2 |
| | Difference for significance (5% level) | 8.5 | 9.6 | 6.4 |

A regular double-disk opener with flat, bevel-rim press wheels set with about ¾-inch between the wheels was used for a check or comparison. The results are shown in line 1 of table 2. It was the regular equipment combination which we had previously found to give the best emergence under most conditions. Lines 2 and 3 show comparisons with the deep-concavity type press wheels more commonly supplied on beet planters. When set close together the deep-concavity press wheels gave practically the same emergence as the bevel-rim press wheels set apart, but when the deep-concavity press wheels were set apart, as they usually are, the emergence averaged poorer. This confirmed the previous year's experience.

The equipment which gave the best emergence of all was a special plate-type sprocket or toothed wheel used between the deep-concavity press wheels as pictured in figure 1. The points of the teeth were not quite as high as the edge of the wheel rim and the base of the points was about even with the center of the concave rim. The emergence with this equipment, given in line 4 of table 2, was significantly better than the check planting shown in line 1. In fact, it was the only equipment which was consistently much better than the check. The cooperative planter test plots of the Colorado Agricultural Experiment Station and the Beet Sugar Development Foundation showed similar improved seedling emergence with this type of equipment. This press-wheel modification seems to be one of the better and most consistent improvements in press wheels so far developed. The wheels might ball up with soil in moist seedbeds so two sprocket-type wheels of half the thickness with one larger and with a larger center than the other might be a better combination.

The data in lines 5, 6, 7, and 8 are for four different combinations of special press wheels. Figure 2 shows the equipment used for line 8 and consists of two regular cultipacker wheels followed by two special Sishc wheels. The two cultipacker wheels alone were used in line 5. Figure 3 shows the tandem use of Sishc press wheels, on which data are reported in line 7, and for the data in line 6 the single rear wheel was removed. Only the heavy and awkward tandem combination of the two pairs of each type of wheels showed consistent improvement and this was not significant.

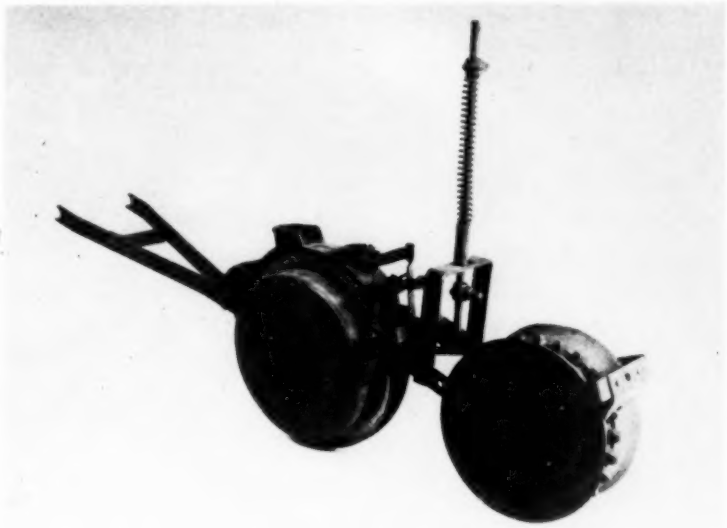


Figure 1.—The use of a plate-type sprocket or toothed wheel between the press wheels consistently improved seedling emergence as compared to press wheels without the special wheel between.

A special set of press wheels consisting of two tandem overlapping pairs of heavy cast-iron wheels with steep-angled rims were tested again this year. This set of wheels, which is shown in figure 4, weighed 70 pounds. The emergence data tabulated in line 9 showed these wheels to give a significantly poorer emergence than the check. In two plantings a year ago these wheels gave somewhat better emergence than the check, but on a loose, dry seedbed they continually caused trouble because of cutting in too much and failure to turn. These press wheels seem to be like several other types of planting equipment tested for improved seedling emergence. The results are erratic, being better than the check one year or one planting and poorer the next.

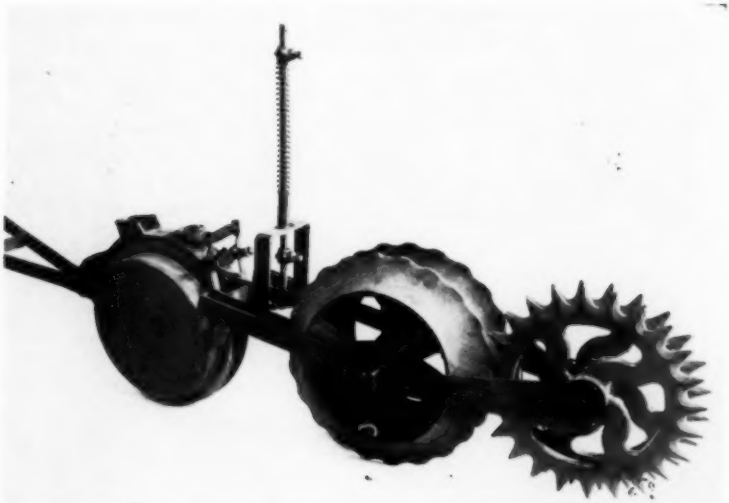


Figure 2.—A press-wheel combination of two cultipacker and two Sishc wheels gave some consistent improvement in seedling emergence, but the improvement was not significant and the equipment was heavy and awkward.

Figure 3.—The Sishc press-wheel combination gave no improvement and with a damp soil surface was poor as it picked up soil.

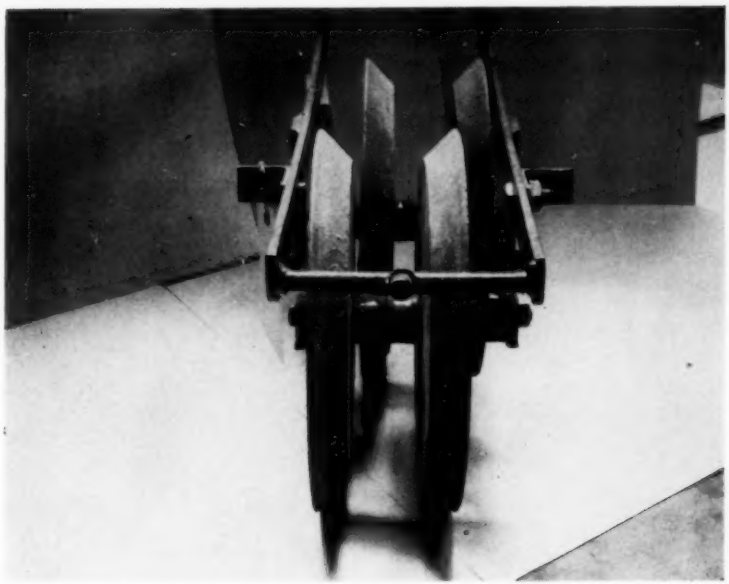


Figure 4.—This special set of heavy, steeply beveled-rim press wheels was significantly poorer than the regular press wheels.

The effect of the use of a safety fertilizer boot on both emergence and seed distribution has been frequently questioned. The boot on a John Deere disk opener is normally used between the disks. This equipment set-up and a special set-up with the boot offset just outside of the disk, as shown in figure 5, were both tested, but no fertilizer was used. The blade on the boot has a slight angle with the line of travel, thus giving a side pressure against the soil as the opener is pulled forward. The boot was offset in the direction to give this side pressure against the seed or toward the right as seen in figure 5. The purpose of offsetting the boot was two-fold. First, it removed the blade from between the disks where the seed had been dropped and thereby reduced the tendency to disturb the placement of the seed. Second, it gave this side pressure against the seed which was thought might close the furrow with moist soil around the seed and give better firming of the soil and thus improve germination and seedling emergence.

Lines 10 and 11 give the emergence data when using the fertilizer boot in normal and offset positions respectively. It will be noted that in normal position it significantly reduced seedling emergence as compared to the check, line 1. This probably resulted from loosening of the soil around the seed and leaving air spaces that permitted a drying-out action. On the other hand, on the first planting, when the boot was offset, it improved

emergence over the check. The second planting, with the offset boot, went in poorly because of improper setting of the boot, and wedging which frequently stopped the disk. Consequently, plowing in of the opener resulted. The boot blade must be set largely behind the disk, as shown in figure 5, to prevent soil wedging between the two and stopping the disk. If the second planting with the offset boot had gone in smoothly—as smoothly as the first one—I believe the emergence would have been better. Even with the poor operation on the second planting, it gave practically the same emergence as the check planting.

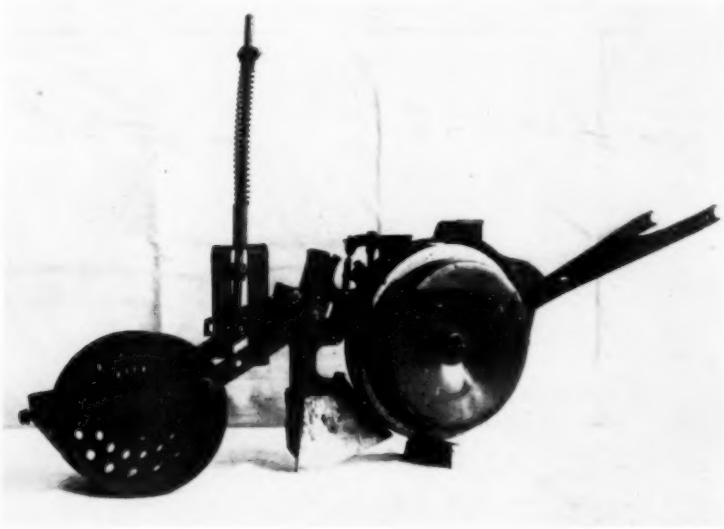


Figure 5.—Offsetting the safety fertilizer boot on this opener very significantly improved the seedling emergence as compared with the boot in normal position.

Seedling distribution comparisons were also made between tests with the fertilizer boot and the check planting. For some unknown reason the uniformity of seedling distribution was practically the same when the boot was offset and when it ran between the disks, on or against the seed, even though it was expected to be better when offset. In both cases it was considerably poorer than the check, but not quite significantly so. The fertilizer boots were used only for the set-ups reported in lines 10 and 11.

The equipment used for trials reported in lines 12, 13, 14, 15, 17 and 18 has all been used in the last 2 years and has shown improvement or promise at one time or another. This year's tests showed all of it to be poorer or no better than the check in obtaining increased seedling emergence. For line 12 an angled bar, extending back and down between the

disks, was used to flatten the bottom of the opened furrow. For line 13 a small plowlike device, mounted between the disks, was used to move a small amount of moist soil from the side of the bottom of the opened furrow over the seed. A combination of these two attachments was used in line 14. A small, sharp edged, runnerlike shoe to divide and flatten the bottom of the opened furrow was used for line 15. A small, wedge-shaped, flat-bottom shoe mounted on the front side of the seed tube was used for line 17. This seed tube came down the rear or fertilizer spout in the disk opener. A round-bottom shoe to press down and flatten the furrow bottom was used for line 18.

The attachment used between the opener disks for line 16 was a combination of the type of runnerlike shoe of line 15 and the seed coverer of line 13 which was new this year. It is shown in figure 6. In the past year or two we have frequently found that some modification of the bottom of the opened furrow, like flattening, has improved the seedling emergence obtained. Also a method of covering the seed with a small amount of moist soil before the seed furrow was filled and pressed down has been beneficial. These ideas were combined in this attachment, but the resulting seedling emergence was poorer than the check.

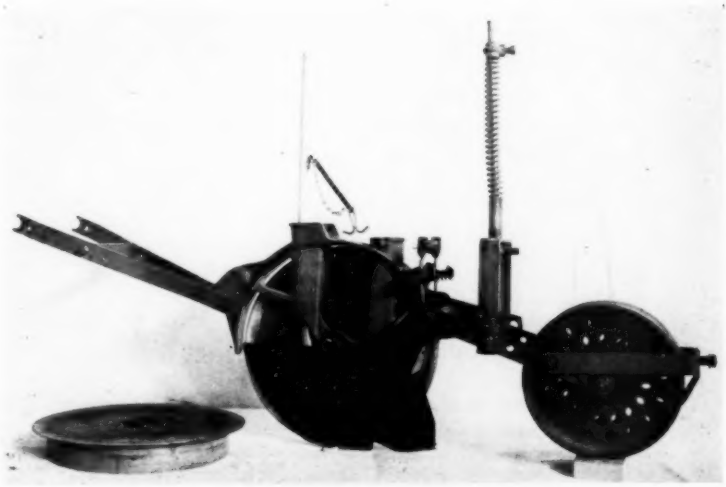


Figure 6.—This combination runner or shoe and seed coverer used between the disks did not improve seedling emergence.

A regular John Deere runner opener was used for lines 19 and 20. In the first case flat-rim press wheels were used and in the second deep concavity press wheels set close together were used. Both tests gave much the same results, confirming results with the disk opener with the same

type press wheels as shown in lines 1 and 3. The runner openers gave somewhat poorer emergence on the first planting and slightly better on the second, averaging practically the same as the disk-opener tests with similar press-wheel arrangements.

In addition to the comparisons of the seedling emergence with different equipment a good comparison of the effect on emergence of two different types of seedbed preparation was obtained from this set of planter tests. The seedbed for the first planting in mid-April had been fitted for a week or so before planting and had received about .4 inch of precipitation, mostly rain, which had settled and firmed it somewhat during that time. Just before planting half of the seedbed was spike-tooth harrowed twice to loosen up the soil. As mentioned before, the planting was begun on April 14, interrupted by a snow of .13 inch precipitation on the 15th and a full set of treatments put in on the 17th. The seedling emergence counts with the different equipment were grouped and analyzed so that an emergence comparison could be made on the harrowed or looser seedbed and on the unharrowed or firmer seedbed.

The seedling emergence on the harrowed and unharrowed sections are shown in table 3. Apparently the freshly harrowed seedbed was not quite firm enough on April 14 as the seedling emergence from that day's planting was significantly better on the unharrowed seedbed. Apparently the .13 inch precipitation on the 15th settled the harrowed ground sufficiently to give a reversal of results for the emergence on the harrowed ground was significantly better on the April 17 planting. The average of the two plantings 3 days apart showed no significant difference between the harrowed and unharrowed seedbed.

**Table 3.—Effect of seedbed harrowing on seedling emergence.**

| Treatment | Percent seedling emergence | | |
|---|---|---|---|
| | Before snow | After snow | Average |
| Harrowed before planting | 66.5 | 67.2 | 66.9 |
| Unharrowed before planting | 70.0 | 64.5 | 67.3 |
| Difference for significance | 3.92 | 2.25 | 1.95 |

The seedling emergence data from this year's planter plots in many instances do not substantiate the results with the same equipment in the past year or two. This variation in results from year to year and from one planting date to another bears out the experience on other sets of plots where seedling emergence is being studied. It indicates that climate, seedbed variation and other factors greatly influence the comparative seedling emergence results obtained with different planting equipment. Planter set-ups which give improved emergence one time and poorer results than regular equipment the next can be recommended only with reservations, if at all. Development to improve this planter characteristic will have to continue until consistent results are obtained.

Some equipment characteristics have been consistent and can be recommended. One of these, which should be repeatedly emphasized, is the proper depth of planting. Early plantings, in the northern Colorado districts at least, should be planted shallower to improve emergence while the later plantings should go in somewhat deeper. The seed should be well firmed in the soil. Improved seedling emergence can be obtained by using suitable press wheels, properly adjusted, or press-wheel modifications or perhaps some other device such as the offset fertilizer boot, used to improve the firming of the soil about the seed. Some modification of the bottom of the seed furrow, like flattening, smoothing or firming, seems desirable but the proper device or method to give consistent results apparently has not been developed so far.

# The Relationship of Seed and Cell Size to Planter Performance

R. D. Barmington[1]

Difficulties arising from variations in the physical characteristics of sugar beet seed has lead to a study of planter performance as it is affected by the seed. Quite often actual seeding rates obtained in the field do not correspond to the calculated seeding rate, and emergence patterns have indicated that something has happened in the planting process which was not foreseen. A break down of some of the variables involved indicates that at least part of the trouble can be traced to the wide variation in seed size fractions within a given size range, and perhaps to differences in density due to different methods or sequences used in processing the whole seed. Some of the difficulties encountered can be traced to variations in the metering devices of planters where the planter cell volume varies a great deal between planters. This cell variation along with the wide range in seed size may account for some of the variations in the field.

If 7- to 10/64-inch processed seed is being considered, it can readily be shown that a large percentage of seed in the 7- to 8/64-inch size range may nearly double the number of seeds planted per acre compared with seed containing a high percentage in the 9- to 10/64-inch bracket. A sphere 10/64 inch in diameter contains 2.914 times the volume of a sphere 7/64 inch in diameter and very often two 7/64 seeds will be picked up in a seed-plate cell which was intended to pick up and drop only one seed piece. In addition to planting more seed pieces than desired, this has the added disadvantage of grinding and damaging the pieces planted. Apparently, from the test conducted, a small increase in plate cell size increases the percentage of cell fill very rapidly when the seed used contains a high percentage of the small sizes.

A test to determine cell fill as affected by plate speed and seed size was conducted in the laboratory using as many commercial planters as could be obtained. The physical characteristics of the seed are shown in table 1 and it was with this seed that the cell fill and plate speed tests were made. The results of this test are shown in table 3 and figures 1 to 11. Table 2 shows the results of plate cell fill for three different plate-type planters using a constant plate speed and changing the size of seed and the method of processing.

[1]Associate Research Engineer, Colorado Agricultural Experiment Station, Colorado A & M College, Fort Collins, Colorado.

Scientific Journal Series No. 268, Colorado Agricultural Experiment Station.

Table 1.—Physical characteristics of seed.

| Great Western Decorticated Seed No. 268<br>7/64 inch to 10/64 inch, 45,880 Seedballs per pound | |
|---|---|
| **Seed size fractions** | |
| Over 10/64 inch | 0.7 percent |
| 9/64 inch to 10/64 inch | 13.3 percent |
| 8/64 inch to 9/64 inch | 45.0 percent |
| 7/64 inch to 8/64 inch | 35.1 percent |
| Under 7/64 inch | 5.9 percent |
| Total | 100.0 percent |

Table 2.—Cell fill and seed size.

**American Crystal Seed**
**Cell fill for John Deere No. 64 Planter**
**Cell diameter .168 inch**
**Plate speed 55 ft./min.**

| Kind and size of seed | Cell fill percent | Seedballs per pound | Seed damage* percent |
|---|---|---|---|
| Decorticated 7-10/64 seed | 89.0 | 32,760 | 1.45 |
| Segmented 7-10/64 (before gravity table) | 99.2 | 46,960 | 2.50 |
| Segmented 9-10/64 (before gravity table) | 90.5 | 37,440 | .55 |
| Segmented 8-9/64 (before gravity table) | 97.5 | 48,250 | 1.31 |
| Segmented 7-8/64 (before gravity table) | 142.5 | 61,160 | 11.30 |
| Segmented 7-10/64 (after gravity table) | 83.0 | 40,070 | 1.60 |

**Cell fill for International 40 Planter**
**Cell diameter 11/64 inch**

**Plate speed 50 ft./min.**

| Kind and size of seed | Cell fill percent | Seedballs per pound | Seed damage* percent |
|---|---|---|---|
| Decorticated 7-10/64 | 104.0 | 32,760 | 0.42 |
| Segmented 7-10/64 (before gravity table) | 128.5 | 46,960 | 0.97 |
| Segmented 9-10/64 (before gravity table) | 105.0 | 37,440 | 0.47 |
| Segmented 8-9/64 (before gravity table) | 134.0 | 48,250 | 0.48 |
| Segmented 7-8/64 (before gravity table) | 219.0 | 61,160 | 2.24 |
| Segmented 7-10/64 (after gravity table) | 110.5 | 40,070 | 1.45 |

**Cell fill for Rassmann Planter**
**Cell diameter 11/64 inch**

**Plate speed 35 ft./min.**

| Kind and size of seed | Cell fill percent | Seedballs per pound | Seed damage* percent |
|---|---|---|---|
| Decorticated 7-10/64 | 96.3 | 32,760 | 0.98 |
| Segmented 7-10/64 (before gravity table) | 117.3 | 46,960 | 2.89 |
| Segmented 9-10/64 (before gravity table) | 97.4 | 37,440 | 1.11 |
| Segmented 8-9/64 (before gravity table) | 125.0 | 48,250 | 2.80 |
| Segmented 7-8/64 (before gravity table) | 164.0 | 61,160 | 3.78 |
| Segmented 7-10/64 (after gravity table) | 99.5 | 40,070 | 1.75 |

*Percent passing through a 6/64 round-hole screen.

Table 3.—Cell fill and seed damage.
Data obtained from 10-minute runs with seed hoppers one-half full.

| Planter | Plate speed ft./minute | Percent cell fill | Percent seed damage |
|---|---|---|---|
| John Deere No. 55 | 10 | 135.7 | 3.88 |
| | 20 | 130.7 | 4.16 |
| | 40 | 117.8 | 3.34 |
| | 60 | 111.0 | 2.90 |
| | 80 | 106.0 | 2.42 |
| | 100 | 101.4 | 3.32 |
| | 140 | 90.1 | 3.63 |
| | 180 | 76.4 | 3.87 |
| John Deere No. 64 | 10 | 111.0 | 7.21 |
| | 20 | 111.3 | 8.15 |
| | 40 | 100.5 | 6.32 |
| | 60 | 97.8 | 6.17 |
| | 80 | 89.8 | 4.78 |
| | 100 | 82.8 | 4.04 |
| | 140 | 63.7 | 5.02 |
| | 180 | 43.7 | 5.07 |
| International Harvester Company No. 40 | 10 | 154.7 | 7.70 |
| | 20 | 153.3 | 6.99 |
| | 40 | 144.0 | 6.40 |
| | 60 | 153.8 | 6.30 |
| | 80 | 127.0 | 6.10 |
| | 100 | 116.8 | 6.44 |
| | 140 | 93.5 | 6.20 |
| | 180 | 85.0 | 8.54 |
| Paul Milton | 10 | 148.3 | 11.54 |
| | 20 | 147.3 | 9.7 |
| | 40 | 127.8 | 10.45 |
| | 60 | 122.0 | 8.65 |
| | 80 | 107.3 | 7.59 |
| | 100 | 77.8 | 5.37 |
| | 140 | 64.4 | 8.49 |
| | 180 | 47.8 | 9.80 |
| Rassmann | 10 | 106.1 | 8.25 |
| | 20 | 106.1 | 6.42 |
| | 40 | 99.0 | 4.13 |
| | 60 | 85.0 | 4.94 |
| | 80 | 73.8 | 5.11 |
| | 100 | 63.6 | 6.89 |
| | 140 | 46.6 | 5.82 |
| | 180 | 36.6 | 8.56 |
| Olson | 10 | No data | No data |
| | 20 | 94.4 | 2.19 |
| | 40 | 70.0 | 1.97 |
| | 60 | 73.7 | 2.49 |
| | 80 | 55.3 | 1.56 |
| | 100 | 53.6 | 2.63 |
| | 140 | 25.9 | 2.66 |
| | 180 | 16.6 | 4.57 |
| Planet Jr. | 12.9 | 129.2 | 2.32 |
| | 20 | 104.6 | 7.41 |
| | 40 | 46.8 | 8.34 |
| | 60 | 34.8 | 7.41 |
| | 80 | 22.7 | 2.13 |
| | 100 | 15.1 | 2.56 |
| | 140 | 8.02 | 3.45 |
| | 180 | 4.74 | 4.54 |

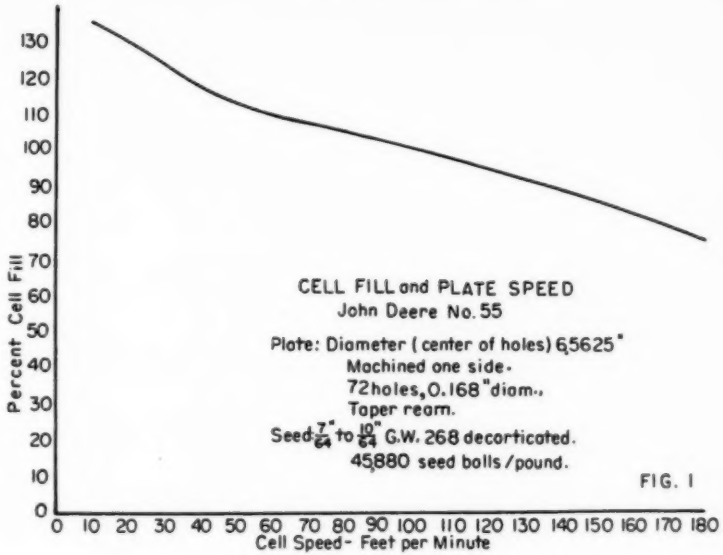

Percent Cell Fill
130
120
110
100
90
80
70
60
50
40
30
20
10
0
CELL FILL and PLATE SPEED
John Deere No. 55
Plate: Diameter (center of holes) 6.5625"
Machined one side.
72 holes, 0.168" diam.,
Taper ream.
Seed 7/64" to 10/64" G.W. 268 decorticated.
45,880 seed balls/pound.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
Cell Speed - Feet per Minute

FIG. 1

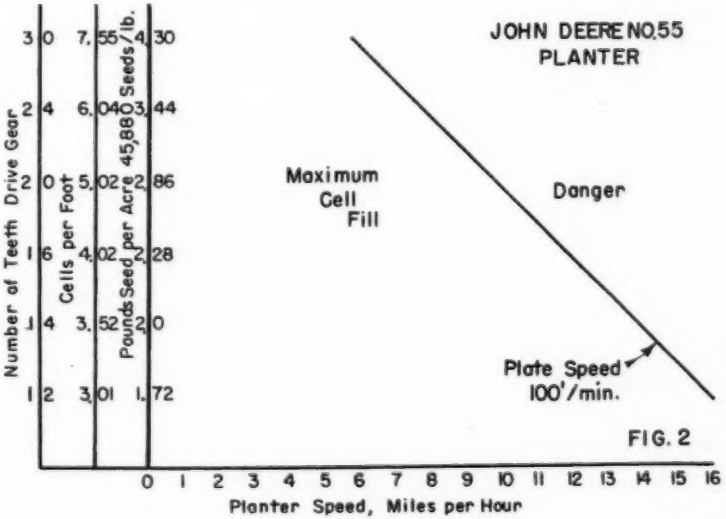
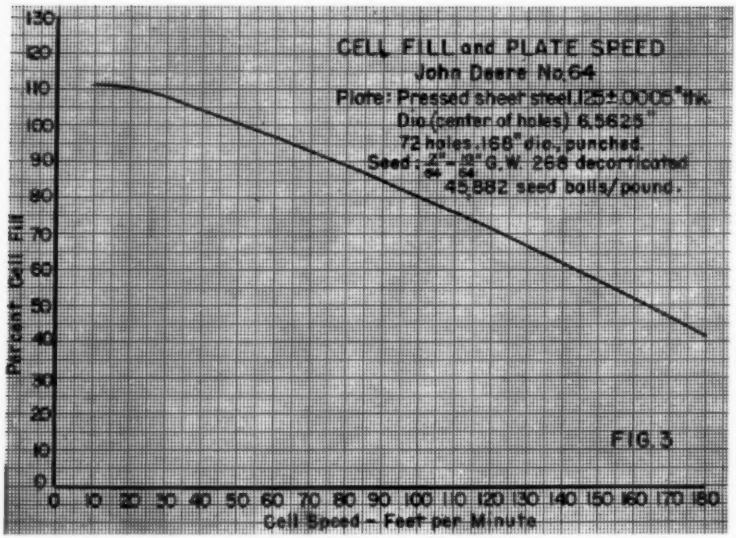
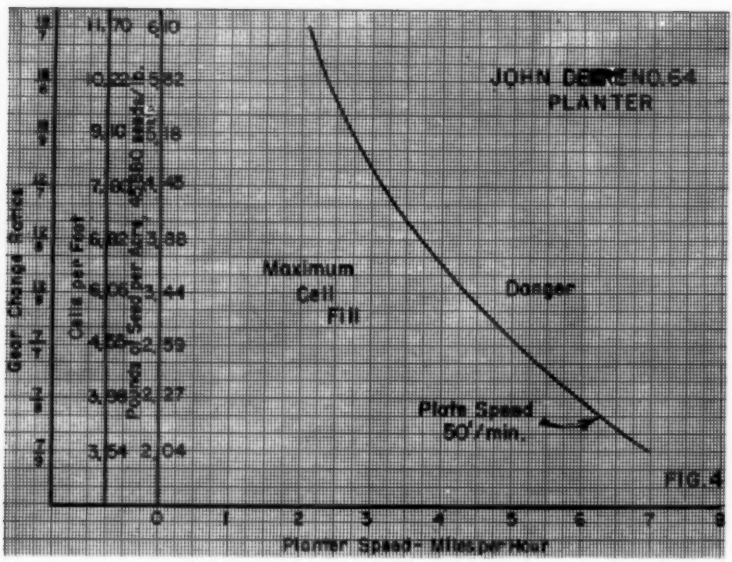
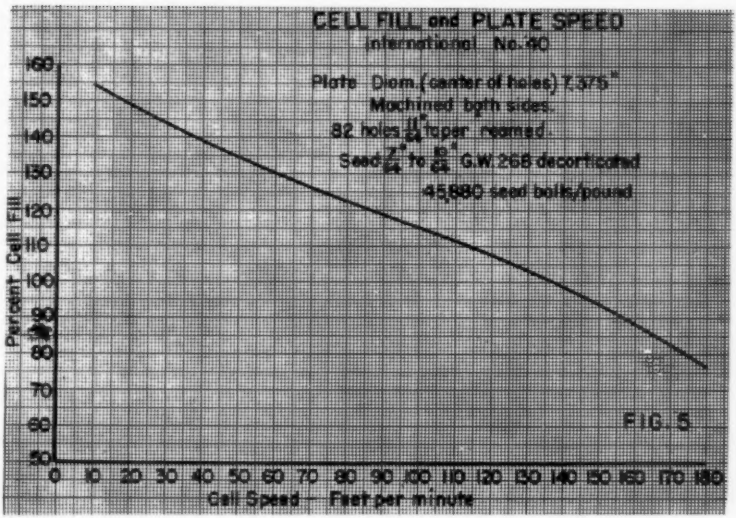
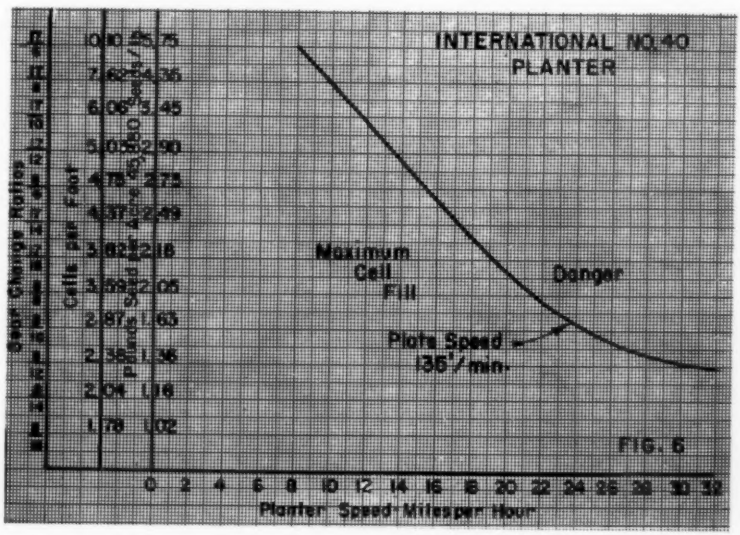

Number of Teeth Drive Gear
3 0 7.55 4.30
2 4 6.04 3.44
2 0 5.02 2.86
1 6 4.02 2.28
1 4 3.52 2.0
1 2 3.01 1.72
Cells per Foot
Pounds Seed per Acre 45,880 Seeds/lb.
JOHN DEERE NO. 55
PLANTER
Maximum
Cell
Fill
Danger
Plate Speed
100'/min.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Planter Speed, Miles per Hour

FIG. 2


CELL FILL and PLATE SPEED
John Deere No.64
Plate: Pressed sheet steel .125±.0005" thk.
Dia. (center of holes) 6.5625"
72 holes .168" dia., punched.
Seed: 2"-16" G.W. 266 decorticated
45,882 seed balls/pound.
Percent Cell Fill
Cell Speed - Feet per Minute
FIG. 3


JOHN DEERE NO. 64
PLANTER
Maximum
Cell
Fill
Danger
Plate Speed
50 r/min.
Gear Change Ratios
Cells per Foot
Planter Speed - Miles per Hour
FIG. 4


CELL FILL and PLATE SPEED
International No. 40
Plate Diam. (center of holes) 7.375"
Machined both sides.
82 holes 11/64" taper reamed.
Seed 7/64" to 8/64" G.W. 268 decorticated
45,880 seed bolts/pound
Percent Cell Fill
Cell Speed — Feet per minute
FIG. 5


INTERNATIONAL NO. 40
PLANTER
Maximum Cell Fill
Danger
Plate Speed 135'/min.
Seed Change Ratios
Cells per Foot
Planter Speed Miles per Hour
FIG. 6

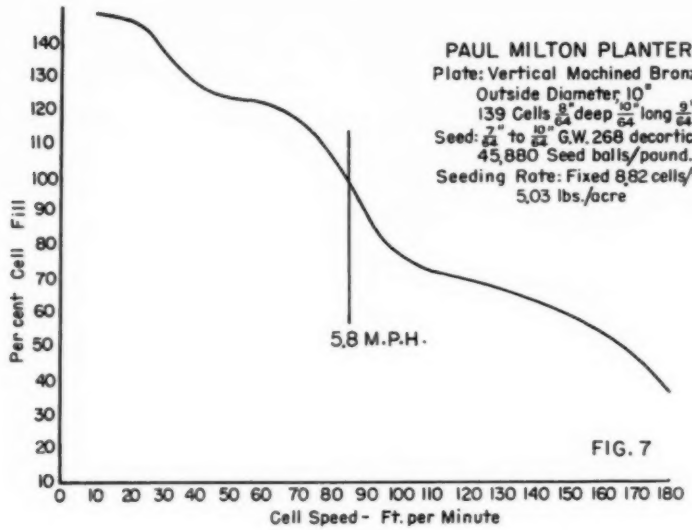

PAUL MILTON PLANTER
Plate: Vertical Machined Bronze
Outside Diameter 10"
139 Cells 8/64" deep 10/64" long 9/64" wide
Seed: 7/64" to 10/64" G.W. 268 decorticated
45,880 Seed balls/pound.
Seeding Rate: Fixed 8.82 cells/ft.
5.03 lbs./acre
5.8 M.P.H.
Per cent Cell Fill
Cell Speed - Ft. per Minute

FIG. 7

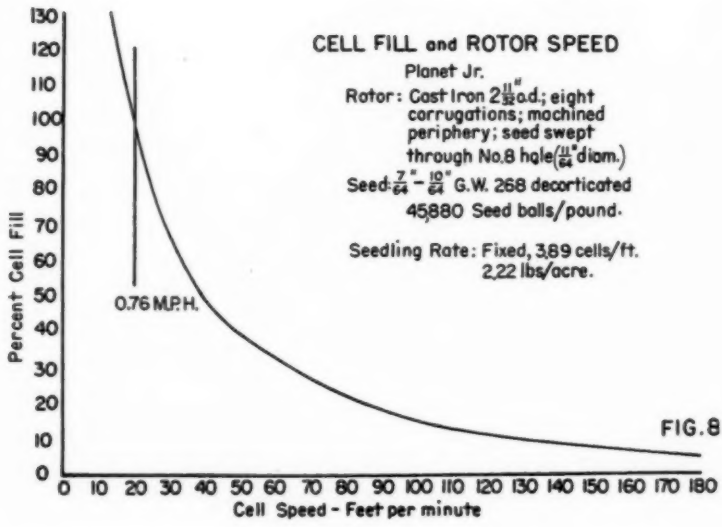
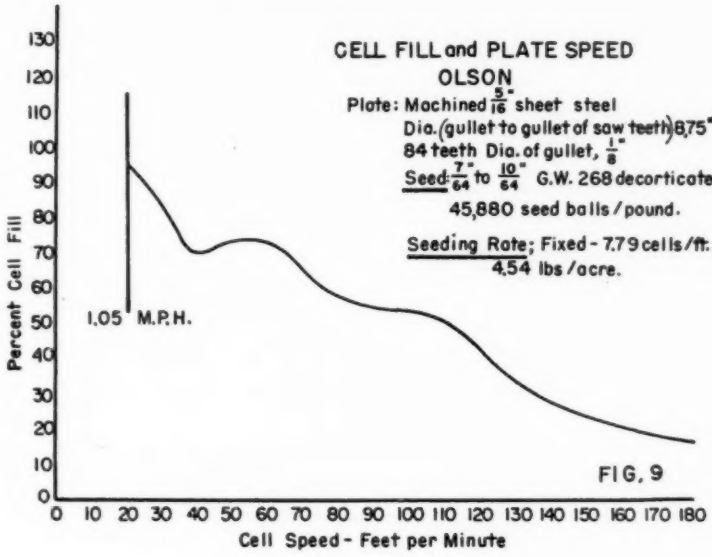
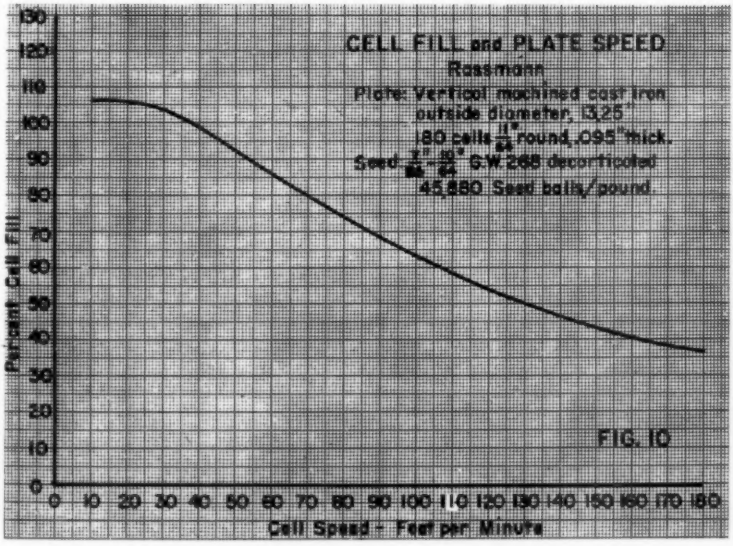
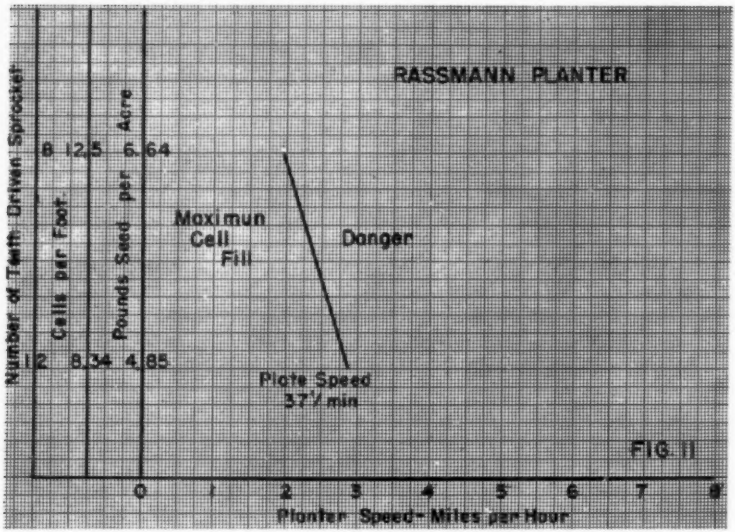
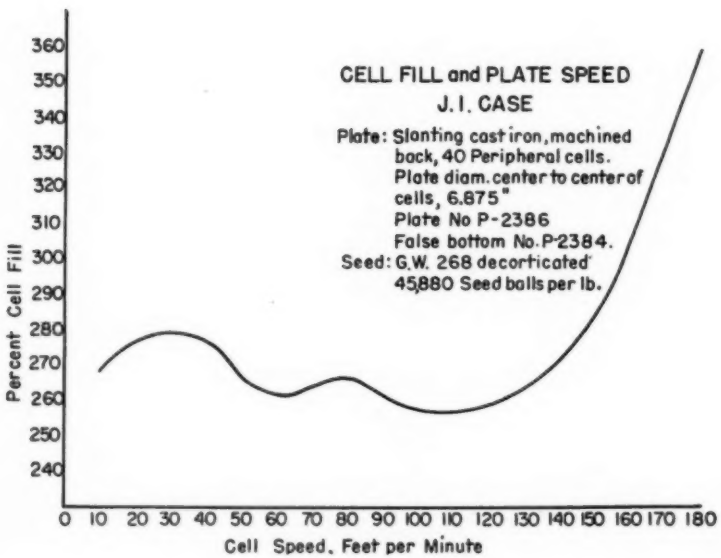

CELL FILL and ROTOR SPEED
Planet Jr.
Rotor: Cast Iron 2 11/32" o.d.; eight corrugations; machined periphery; seed swept through No.8 hole (11/64" diam.)
Seed: 7/64" - 10/64" G.W. 268 decorticated
45,880 Seed balls/pound.
Seedling Rate: Fixed, 3.89 cells/ft.
2.22 lbs/acre.
0.76 M.P.H.
Percent Cell Fill
Cell Speed - Feet per minute

FIG. 8


CELL FILL and PLATE SPEED
OLSON
Plate: Machined 5/16" sheet steel
Dia. (gullet to gullet of saw teeth) 8.75"
84 teeth Dia. of gullet, 1/8"
Seed: 7/64" to 10/64" G.W. 268 decorticated
45,880 seed balls / pound.
Seeding Rate; Fixed - 7.79 cells/ft.
4.54 lbs / acre.
1.05 M.P.H.
Percent Cell Fill
Cell Speed - Feet per Minute
FIG. 9


CELL FILL and PLATE SPEED
Rassmann
Plate: Vertical machined cast iron
outside diameter, 13.25"
180 cells 11/64" round .095" thick.
Seed 7/64" - 10/64" G.W. 268 decorticated
45,880 Seed balls/pound.
Percent Cell Fill
Cell Speed - Feet per Minute
FIG. 10


RASSMANN PLANTER
Number of Teeth Driven Sprocket
Cells per Foot
Pounds Seed per Acre
8 12.5 6.64
12 8.34 4.85
Maximun Cell Fill
Danger
Plate Speed 37½ min
FIG. 11
0 1 2 3 4 5 6 7 8
Planter Speed - Miles per Hour


CELL FILL and PLATE SPEED
J. I. CASE
Plate: Slanting cast iron, machined back, 40 Peripheral cells.
Plate diam. center to center of cells, 6.875"
Plate No P-2386
False bottom No. P-2384.
Seed: G.W. 268 decorticated
45,880 Seed balls per lb.
Percent Cell Fill
360 350 340 330 320 310 300 290 280 270 260 250 240
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
Cell Speed, Feet per Minute

Eight makes of planters were tested, but since the Case planter used was not a production model it will not be included in the report. The other seven are: John Deere No. 55, John Deere No. 64, International No. 40, Paul Milton, Planet Jr., Olson and Rassmann. Other planters would have been included if they could have been obtained in time for the test.

The seed in table 1 was Great Western No. 268 processed at the Sterling, Colorado, plant. It was decorticated 7- to 10/64-inch size having a rather high seedball count per pound. The seed used in table 2 was American Crystal processed at the Rocky Ford, Colorado, plant. The seed was run through the sampling machine at the Seed Laboratory of the Colorado Agricultural Experiment Station to get samples for seedball counts. All calculations were determined by weight on a sensitive balance after the seedball count had been made. The Great Western No. 268 seed had a seedball count of 45,880 per pound while the American Crystal decorticated sample which was tested had 32,760 seed pieces per pound. H. W. Dahlberg, Research Manager for The Great Western Sugar Company, says that different varieties will vary between themselves to this extent.

In general the cell fill for all plate planters was higher using 7- to 10/64-inch decorticated seed with the correspondingly larger plate cells this year than they were last year using 7- to 9/64-inch segmented seed and smaller cells. This seems to bear out the idea that wider ranges in seed size are used at the expense of precision planting. Table 3 summarizes the results of the plate speed and cell fill test and shows the corresponding seed damage. The seed damage was measured as the percentage of dust and broken particles which pass through a 6/64-inch round-hole screen after passing through the planter metering device.

The slope of the curve on the cell fill versus plate speed graphs indicates to some extent the sensitivity of the planter with respect to speed. In general the flatter the curve the less sensitive it is to increased speeds. The highest point on the curve at slowest speeds is some indication of how much too large the plate cell is for the seed being used. As an example, the 11/64-inch cell in the International No. 40 planter has a volume of 13.5 percent greater than the .168-inch cell in the John Deere No. 64 planter. At the very slow plate speed of 10 feet per minute both planters should pick up seed directly proportional to the volume of the planter cell. In this case the International had 154.7 percent cell fill and the John Deere 111 percent cell fill. This brings out the delicate relationship between seed size and cell size.

Table 2 again shows the effect of changing the size of seed on the percentage of cell fill. The International No. 40 in this case dropped more than twice as many seed pieces when 7- to 8/64-inch seed was used as it

did when 9- to 10/64-inch seed was in the hopper. The John Deere increased 55 percent using the small seed and the Rassmann increased 68 percent.

In the field where laboratory control is impossible it might be desirable to divide the present 7- to 10/64-inch seed into two sizes. One size, from 7- to 9/64-inch using a 10/64-inch plate cell for growers interested in the highest possible number of single-germ seeds and the other, from 9- to 10/64-inch using a 11/64-inch plate cell, for accurate planting of seed pieces slightly higher in sprout count. If the problem of seed processing and distribution were not too great, more accurate sizing would be definitely advantageous. It is quite evident that anything that could be done to produce a more uniform size of seed would be highly beneficial. Keeping the plate-cell size as small as possible to accommodate the largest seed in the size range will help. By using the smallest plate cell possible and low planter speeds a fairly good job of planting can be done.

# General Agronomy

# Space Relationships as Affecting Yield and Quality of Sugar Beets

G. H. Coons[1]

THE EFFECTS OF SPACE relationships on yield and quality of sugar beets have received consideration from the very beginning of sugar beet culture. Achard in his treatise on the sugar beet gave detailed directions that the beets were to be grown in rows 12 inches apart and at 12-inch spacings in the row. The placement was to be such that a staggered arrangement resulted. In view of Achard's careful approach to similar problems with other crop plants, it seems a safe assumption that this recommendation was based upon experimental evidence.

The industry started out with a dense population of plants which may very well have suited plant culture performed exclusively with hand labor. As machines began more and more to replace hand labor, and as horse-drawn and motor-driven machines were introduced, changes from the close patterns were necessary.

In the early period, replicated experimental trials to determine space relationships were few if any. Judgment was based on the treatment giving the largest yield. Obviously, replication in time was necessary to establish a conclusion and to avoid the effects of chance occurrence. This early work will be summarized. It furnished the basis for the more modern agronomic experience. There may be some surprises. Sugar beet agriculture arrived at the satisfactory space allotment per plant by trial and error methods. In this regard, the sugar beet does not differ from corn, potatoes, soy beans or other important crop plant, for with these crop plants also, the accepted space allotments per plant are the result of farm experience rather than exhaustive agronomic experiment.

European technology largely dominated sugar beet agriculture from 1890 to World War I. American practice was often influenced by its teachings. One of the surprises will be the nature of the experimental work on which recommendations were based and may explain why European advice was not wholly followed in our agriculture. Another surprise may be the significance of the American contributions to this field of work. It will be seen that our research pioneered in application of the newer agronomic methods to the problems of space relationships.

Because of the complexity of the problem and the need for taking cognizance of the changing nature of sugar beet agriculture, final recommendations as to optimum space allotments for the sugar beet cannot be made. These must be determined by studies conducted under particular soil and climatic conditions and must take into account the type of sugar

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beet culture to be employed. The plant reactions must be recognized as the key factors in the situation. Agronomic techniques available for such a research attack will be reviewed and a few beacons will be set up to guide a renewed and vigorous research program.

### Early Work on Spacing of Sugar Beets

Probably in his day, Hollrung (24)[2] had the most authoritative voice among sugar beet technologists. In 1894, on basis of experiments conducted by Marek, Ladureau and Petermann, he concluded that the greater the available space, the larger the beet, and that foliage size dropped off with decrease of growing space. He stated that with narrow spacing, sugar beets yield more sugar than with wide placement, and that beets standing close together contain not only a greater weight of sugar, but lesser amounts of non-sugars, two items of greatest importance in processing.

Although Hollrung's conclusions may be readily accepted since these plant reactions are not greatly at variance from what would be expected, exception could be taken to the meagerness of the experimental data from which they were drawn. In the experiments cited, row widths ranged by 2-inch steps from about 14 inches to 20 inches. Intervals in the row were approximately 8 inches or 10 inches. Within a given experiment the results were not concordant; judgment was commonly based upon the largest value. Replication was scanty or non-existent. Whereas at least 10 percent or more as a difference would be required even to approach significance, the values on which decisions were based were about 100 or 200 pounds of sugar per acre. Obviously such differences do not fall outside of chance occurrences.

As extensive tests as any, and, in their day, very influential, were those of Vanha and his associates (39). Here, we find an experiment on sugar beet space allotments, in which some spacings occurred in 3-fold replication, some in 2-fold, and one as a single plot. As luck would have it, the last named turned out to be the highest yielder. The unbalanced experimental design makes determination of statistical significance impossible, but here again one could assume that at least a 10 percent differential would be required for significance. The tests compare 14-, 16-, and 18-inch row widths, as combined with 8-, 10-, and 12-inch row intervals. Obviously only very precise, many-times replicated experiments could appraise such small differences in space allotments. It is not surprising, therefore, to find that these comparisons in which the space per plant ranged about 112 to 216 square inches gave, in 1902, the highest sugar production per surface unit from the widest spacing, whereas the next highest and differing only by 107 pounds of sugar per acre, was from the closest spacing! Similar experiments (not cited) were conducted by these investigators in 1903 and again in 1905. They were inconclusive, and if anything, contradictory of the 1902 tests. The difference between the highest and lowest value was only 160 pounds sugar per acre, clearly a non-significant difference. In 1905,

[2]The numbers in parentheses refer to literature cited.

other than a suspiciously high value for one trial of the 18- x 10-inch space, all other values fall very close to 4,800 pounds per acre. Inasmuch as the 1903 and 1905 values were so contradictory of the 1902 results, the authors made no attempt to draw conclusions, other than to discuss effects of space on top size.

In 1921, Gerlach (20), also a leader of the industry, deplored lack of adequate experimental evidence on space relationships. Prevailingly sugar beets were grown on a 16- x 10-inch pattern. In his opinion, increase of row width to 19 inches would not be hazardous. He pointed out that 20- x 20-inch spacing as advocated meant reduction of the customary population of 100,000 plants per hectare (about 40,000 per acre) to 40,000 per hectare (about 16,000 per acre) so that average size of root would need to increase 2½ times if yields were not to go down. At the same time sucrose percentage would need to be maintained if sugar production were not to drop. Gerlach pointed out that experimental evidence proved that this does not occur and that some halfway step would be advisable to give 25,000 or, at least, 21,000 plants per acre, so that weight of the average root would only need to increase 1.2- to 1.6-fold. Sucrose percentage would not be seriously affected. Krüger (20, 26) in his discussion of Gerlach's proposals stated that low sucrose percentage of widely spaced beets was merely a matter of ripening. For sugar beets to ripen, nitrogen must be brought to a minimum as evidenced by yellow leaves. This is not reached with widely spaced beets. In a field with little nitrogen reserve, the added nitrogen can quickly and profitably be utilized, then the beets ripened. Narrow placement is necessary since wide spacing brings about unripe beets. In his opinion, row width may be increased to approximately 19 inches, but "we dare not depart from closest possible spacing in the row if we wish to have good beets."

In 1924 Zwoboda (40) attacked separately the problems involved in determining (a) most favorable row width and (b) the best spacing within the row. In a 3-times replicated test with a fixed interval in the row of 12.6 inches, he obtained the highest yield of sugar per acre from a 14.7-inch row width, the 16-inch giving 7 percent less, the 18-inch width 10 percent less, and the 20- to 22-inch widths about 20 percent less than the 14-inch row width. Having settled on the best row width he varied the interval in the row by a 2 inch differential—8-, 10-, and 12-inch spacing—with the result that highest yield of sugar came from the 12-inch row interval, the 10-inch interval being 3 percent less and the 8-inch row interval, 14 percent less. His conclusion, therefore, was that the best pattern is a quadrat about 14.7 x 12.6 inches. This finding is reminiscent of Achard's early recommendation.

In 1927, C. Bonne (4) summarized spacing experiments as conducted at Schlanstedt, Germany, in the period 1923-1928. The various spacings had been tested in 3-fold replications in 1923 and 1924, and in 4-fold replications in 1925-1928. Long, rectangular plots, 3 rows each, with the

center row harvested, were used. Only normal beets growing in complete stands were harvested to determine yields. The results are given only as the combined averages for the 6 years of test. The closest spacing 14.8 x 13.8 inches gave roots with an average weight of 1.166 pounds, whereas the widest spacing 19.7 x 15.8 inches gave roots averaging 1.576 pounds. For the intermediate spacings the root weights follow about a straight line relationship.

Sucrose percentages deviated numerically only by 0.5 from smallest (203 square inches) to largest space allotment (310 square inches). Sugar production was highest in the plots with the smallest space allotment per beet. It dropped about 14 percent below this figure in the largest space allotment, which gave approximately 35 percent more plant room than the smallest. Between the extremes, the production showed a uniform decline.

The work of other European investigations may be briefly cited. Soucek (37) held the space between the rows constant at 42 centimeters (16.8 inches) and had intervals in the row ranging from 6.36 inches to 15.64 inches. The greatest yield came from the beets having the smallest space allotment per plant. The yield of beets with the largest space allotment fell about 16 percent below that of the closely spaced beets. Intermediate spacings were uniformly or regularly disposed between these extremes. It is to be noted that the space allotments in these experiments are all smaller than those of chief interest in American tests.

DeHaan and Klijnhout (13) conducted a population study on three fields of different fertility levels. They determined the space allotment and weight of each plant of a selected strip. The weight data were combined according to space allotments by steps of 200 square centimeters. An average weight was thus determined for each space allotment in each field. From these data, numbers per hectare were computed. The authors had theoretical populations ranging from 40,150 to 110,865 plants. They concluded that to increase the yield of beets, it is necessary to increase the number per hectare above a minimum of about 63,000. Taking 60,000 as a base, the authors computed that increasing the number of beets per hectare by 25 percent, increased the yield of roots almost 8 percent, whereas an increase of 50 percent in the number of plants increased the root weight 13 percent.

Roemer (34, page 168-169) states that in the period 1890-1900, there was a move toward narrow spacing some even going so far as to propose 20 centimeters x 20 centimeters (8 inches x 8 inches) or 33 centimeters x 15 centimeters (about 13 inches x 6 inches). In the period 1906-1916, a common pattern was 37 centimeters x 18 centimeters (about 15 inches x 7 inches). He states further as justifying the change to wider spacing "Newer investigations have shown that the present, highly bred beets will permit recommendations of a spacing formerly out of the question. The argument for this is, above all, that wider row distance permits frequent deep cultivation, considered to be favorable. Under such assumption, a row width of

50 centimeters (20 inches) is permitted and spacing in the row of 20-25 centimeters (8-10 inches), but wider spacing than 20 inches is not safe."

European technology at first recommended close spacings for sugar beets but rather generally moved to wider patterns after World War I. The European literature indicates that managers of estates and technologists arrived at a width of approximately 18 inches between rows and a row interval from 10 to 12 inches as the preferred pattern. Almost from the beginning of the culture of sugar beets in America, close patterns were not recommended unless some factor such as curly top indicated an important reason for crowding the plants (Nuckols, 31). The greater use of machines for planting, cultivation and harvesting as compared with continental Europe was undoubtedly the decisive factor. In a country accustomed to wide rows for corn, 20 inches for sugar beet rows seemed very close indeed. A gain of 10 to 15 percent from close spacing was more than offset by other forms of crop cost, or even by crop loss, as occasioned by reduction of row width. American practice very early took as a standard the 20- x 12-inch pattern. European practice, especially when the use of drills and cultivators increased, accepted a similar pattern.

## Application of Modern Agronomic Techniques

The preceding review of the observational, or trial and error, period of sugar beet agronomy has shown that in spite of the complexity of problems and the shortcomings of the older methodology a solution was reached for the space relation problem then existent. Some recent experimental studies in which statistical controls were employed to safeguard against conclusions being based upon chance occurrence may now be reviewed. This work may be expected to be more efficient than the older work, and it should confirm or deny older conclusions. It should be able to meet new problems with sureness and dispatch. Not all pertinent work can be noticed. Reference will be limited to those contributions that have special interest because of the methodology employed or because they emphasize a new concept or approach to the subject.

One of the first of these studies was made in 1927 in England by W. Engledow and his associates (17). It was essentially a census study of 6 representative beet fields. Numerous sampling stations were established in the fields. By counts of initial stand and by 9 stand counts throughout the season, together with harvest data, the course of the plant populations was followed. Some important conclusions were derived. Loss of plants after seedling emergence was negligible. In each of the 6 fields there was a steady decline of root size with increase in plant population. All the tests that the authors applied supported the conclusion that the number of plants and the yield per unit of length were directly related, or that they were in fact, of the nature of cause and effect. Broadly speaking, soil fertility and culture are the controllable factors that govern yield. The points of practice about which doubt remains are those which affect plant

population. When the definite distances between the rows or between plants have been decided, yield per acre depends very directly upon the extent to which the theoretical "full plant" is secured. Roots that have more than average space grow to more than average size, but every root or gap counts in determining yield per acre. "The beet is a costly crop to grow if only half a full plant is secured."

These authors give an excellent model for a detailed study of plant population by census methods, and their conclusions are noteworthy in placing in relief the importance of soil fertility and cultural treatments as the real determiners of yields, once a reasonable plant population is set up. Their comments on necessity of a "full plant" foreshadowed results obtained independently in the United States.

Brewbaker and Deming (6) made a highly important contribution to the problem of space relationships of the sugar beet. They applied to the data obtained from experiments at Fort Collins, Colorado, in 1930 and 1931, and at Rocky Ford, Colorado, in 1931, the newer statistical techniques. Immer (25) had previously made a start in this direction with his application of the analysis of variance to certain problems of sugar beet plot technique. The authors confirmed that for a unit area the correlation of weight of beets with stand is positive and significant. Within the limits of the tests the relationship is essentially linear. The authors illustrate their finding with a forceful example, pointing out that, as an average, each drop of 10 percent in stand means a drop in yield of 1.25 tons per acre. In the yield and stand study based on competitive beets only, row widths from 18- to 24 inches were used with row spacings from 6- to 16 inches. Heavier tonnages were produced by the 18- and 20-inch row widths than by the 22- or 24-inch widths. As to space interval in the row, the authors call attention to the fact that with 8-inch spacings there are 50 percent more beets per acre than with 12-inch spacings, and 100 percent more than for the 16-inch spacing. The increase of average yield for the 8-inch interval in comparison with that from the 12-inch spacing in the row was not significant. Significant differences in yield were found between 8-inch and 16-inch intervals. These were in favor of the close spacing. A highlight of the paper was the assessment of relative importance between adjustments of row widths or row intervals and uniformity of stand. They found that uniformity of stand is relatively a far more important factor in determining final yield than is the particular row width or spacing used. The authors were aware of the far-reaching effects of their conclusion since they state "The placement of major emphasis on uniformity of stand involves almost every field practice particularly the operations preceding and immediately following blocking and thinning, and, to a somewhat lesser extent cultivation, irrigation and protection against insect pests." An important contribution from this study, and basic in explaining the conclusions drawn, was the evidence that the 8 beets surrounding a blank space in a 20- x 12-inch spacing were so increased in weight that there

was a compensation for 96.2 percent of the loss due to a single missing beet. Other investigators have not obtained so great a compensation (Garner and Sanders (19), Finney (18)).

Another and highly significant contribution in light of later developments was the finding that even if 25 percent of all hills were doubles the root yields were not significantly lowered. This confirmed certain early work that at the time was not fully accepted by growers. More recent work by Deming (14), Nuckols (32), and others (16, 27) have amply verified the finding that in commercial fields a relatively high percentage of doubles and some triples does not significantly reduce yield. In a further follow up of this line of investigation, Deming (15) has shown that so long as hills do not have more than 2 or at most 3 plants, the number of hills per acre and not the plant population is the significant thing affecting yields. A directive is thereby given to agricultural engineers permitting them to concentrate on a pattern of hills, not of single plants.

Nuckols (32) questioned the blanket use of the "competitive" beet technique by showing the futility of seeking to salvage results from an experiment with poor stands by the device of saving a limited number of so-called "normally competitive" samples. Since a plot with 80 percent stand could by certain placement of gaps yield only 10 percent of its beets as growing under normally competitive conditions, it is obvious, he points out, that the poorer stands automatically mean inadequate sampling, and the yields calculated to a 100 percent basis are unreliable. In plots of excellent stands, results from actual plot yields and computed yields from normally competitive beets would tend to merge whereas with gappy stands it is obvious that the beet selected would reflect the competition conditions of its growth. This report had highly salutary effect in curbing misuse of the normally competitive beet technique. It is now retained as a means of judging quality of sugar beet experimental plots since a plot that would not yield chiefly normally competitive beets is likely to show bias. For the selection of sugar samples it has value. Agronomists are becoming increasingly critical of conclusions based upon plots with poor stands.

The British investigators, Garner and Sanders (19), concerned themselves with many of the problems studied by Brewbaker and Deming and by Nuckols. They reviewed earlier work in England citing that of Davies who showed that, within limits, yield was not related to the number of roots per acre but was affected by the distribution. Wide spacing of rows could not be compensated by narrower spacings within the row. They quote Pedersen's work on the relationship of gaps to yield. In these Danish experiments with both sugar beets and mangel-wurzels, the compensation of growth of roots bordering a gap amounted to 76 percent for a single gap, but the percentage of compensation decreased as the size of gap increased. Garner and Sanders' own experiments with sugar beets in 1934 consisted of a 5-times replicated test with row spacings of 12, 18, and 24 inches with intervals in the row of 6, 9, and 12 inches for each row spacing.

In 1936 the same variables were used except the 6-inch row interval was omitted. The authors found that although yields of roots and sugar increased as distance between rows decreased, there is little indication that rows narrower than 18 inches are worthwhile. Spacings in the row from 6 to 12 inches produced no differences in yields of roots or sugar, consequently, for convenience of working a spacing distance in the row of 12 inches is most desirable. The data were further applied to the solution of the problem of effects of gaps on root and top weight. In a dry year the roots immediately surrounding a gap compensate to the extent of 80-89 percent for the missing plant, the allocation to individual neighbors being about inversely proportional to the square of their distance from the site of the gap. In a wet year the compensation was less complete amounting to from 41 to 84 percent. In both years, compensation was less complete for tops than for roots.

From a study of individual root records, the authors, basing their study on plants with no gaps in the immediately surrounding ring, showed that 18 x 9 inches was the optimum spacing. From their experiments they state that 400 plants per plot is necessary to reduce the plot error due to genetic variability to 2 percent of the mean.

Hey and Kemsley (23) in related studies on the same data took into account the effects on the sugar beet plants of very small and very large beets in the surrounding rings of plants Extreme sizes may produce effects comparable with that of the gap itself. Their technique was to select an area covering about 10 to 30 beet sites. The unit area studied was 6 x 3 feet and regression of yield on percentage stand was determined. They compared yields as estimated from 100 percent stands of the "perfect" beet and by the method of regression lines. Since there are gaps in the second ring, a beet in the first ring may tend to become too large and thus cause the central beet to be subnormal. The second method tends to over-estimate, but has the advantage of using all the data.

Other important publications by American and European investigators can be given only brief mention. Brewbaker (7) gave additional data from experiments at Fort Collins and Eaton, Colorado, to reenforce his earlier recommendations for increased population density as a means of increasing yields. Bilian (3) for Czechoslovakia, conducted experiments with 4 varieties of sugar beet and 5 varieties of mangel-wurzels. Yields from plants with 1,000 square centimeters of space were compared with those from 2,000 square centimeters. The smaller space allotment gave the greatest total weight of roots, crowns, leaves and dry substance. Buschlen (8) and Bradford (5) each found that yields were increased by planting in rows closer than 28 inches. Astrand (2) from a statistical study of factory records in Sweden showed that yield of sugar increased with density of plant populations. Dahlberg (10) had made a comparable report of the Swedish experience for 1932, in which fields averaging 16,000 beets per acre gave 10.79 tons as compared with 15.58 tons for fields of 24,000 beets

per acre. He reported that increase in yield due to greater number of plants much more than offsets any decrease due to reduction in size of average beet.

Similar statistical studies of factory data have been made by sugar companies in the United States. The recent study as made by Lill (28) may be cited as indicative of what may be shown from such records. Material for the population study of sugar beets was supplied by Manager John Kelly of the Lake Shore Sugar Company. The data consisted of the tare records for 1938-1942 inclusive with numbers of beets recorded for each sample. Having the weight of the tare sample, the tare, the number of beets, the total weight of clean beets in the sample was obtained. The total weight of clean beets for the samples of a given contract divided by the total number of beets in the samples resulted in an estimated average weight for the individual beet delivered under the contract. The yield per acre in pounds for the contract as obtained from factory records divided by the estimated weight of the individual beet gave the estimated plant population per acre. Factory records also gave the row width for the individual fields. A total of 5,605 fields were included as a total of the 5 years, the numbers ranging from a high of 1,365 fields in 1938 to a low of 913 in 1941. Plant populations ranged from a low of 6,245 to a high of 24,244 per acre. The distribution showed a fairly uniform curve centering at about 14,000 plants per acre. Lill's conclusions were that (a) the relation between plant populations and acre yields, although varying slightly with season, remained essentially the same. The highest yields came from the highest plant populations. (b) Width of row (rows ranged from 22- to 28 inches) had a slight but definite influence upon the relationships, the higher plant populations having been maintained and higher acre yields obtained, on the average, in the fields with narrow rows. (c) The relationship between estimated plant populations and acre yields is essentially linear. The study revealed the arresting fact that plant populations on many commercial fields are too low to give more than half of a possible yield.

Data as used by Lill could become available from all factory districts if the number of beets were systematically recorded for each tare sample. Such data along with factory records would constitute a mine of information for the technologist.

Attention is called to the very useful summarizations made by Armer (1), based on data from The Netherlands (13), Woodland, California, and Granger, Utah. The data were graphed to answer the questions: How does sugar production vary with populations per acre and, with plant populations held constant, how does sugar per acre vary with distribution of plants? When the plant population falls below 25,000 per acre, sugar production was found to drop sharply. Sugar production also was found to drop when the distribution ratio (ratio of row width to row interval) increases beyond 2.0. It is pointed out that these findings completely justify

the customary 20-inch rows with 10- to 12-inch spacing in the row, corresponding, respectively, to about 31,000 and 26,000 plants per acre. These patterns have distribution ratios of 2.0 and 1.67, respectively. Row widths much wider than 20 inches, for example, 26- to 36 inches, will reduce sugar production markedly even if, to maintain population levels, the beets are spaced closely in the row.

Interaction of space allotment with variety and the interaction of space allotment × variety × fertility level have only partially been explored. The information is such as to indicate the desirability of much further investigation.

Lindner (29) in comparing spacing effects upon yield and sucrose varieties found in 1933 that the sucrose variety gave yields little affected by the space allotment, whereas the yield type gave largest production at the narrowest spacing. In 1934, both types gave highest yields at the narrowest spacing. In a series of contributions, Decoux, Vanderwaeren and Simon (cf. summary by Decoux 11:213-229) showed the importance of relatively dense populations of sugar beets per hectare if yields are to be maintained. They concluded (12) that the size of foliar bouquet as characteristic of certain varieties is a factor in determination of the appropriate spacing. However, Ginneken (21) found that a variety with large foliar bouquet at 55,000 plants per hectare (22,260 per acre) gave 10 percent less yield than was obtained from a stand of 70,000 per hectare (28,340 per acre). Lüdecke (30) stated that as width of row is increased, use of nitrogen increases the weight of individual roots, but only proportionately, over-compensation not being obtained. Skuderna and Doxtator (35, 36) conducted studies of spacing effects with varieties of sugar beets at different levels of fertility. They obtained significant differential responses of varieties to both fertilizer and spacing and the first and second order interactions were significant. Thus the techniques of the complex experiment were applied to the problem.

Tolman (38) also employed the techniques of multiple factor experiments to determine interactions between variety, space allotment and fertility level. The varietal responses to the other factors differed significantly and certain interactions appeared significant. It is not unlikely that a given variety may be found to require a definite planting pattern for its best performance. These experiments, taken in connection with others that have been cited (12, 16, 35, 36), indicate that the multiple factor experiment may prove an effective research method, greatly facilitating the experimental attack, and at the same time broadening applicability of findings.

## Discussion

The problems of space relationships of sugar beet consist of a series of interlocking phases involving plant populations, field patterns, compensation for missing hills and tolerance of multiple occupancy of hills. A sugar beet plant is the summation of the environmental factors that im-

pinge upon it, as within the genetic limits, it reacts in response to those factors. Solar radiation, temperature, soil moisture, soil fertility and other factors of the environment in their effects on plant characteristics such as capacity for growth, foliar bouquet, root size and type, and other genetic characters, produce the end result. Usually a single factor cannot be detached from the complex so that its particular influence may be determined but conclusions must be drawn from associated effects.

The slow development of our knowledge with respect to the requirements of the sugar beet and the present status of the rules and recommendations for space relationships find parallels among other crop plants. Space allotments in current use with them are now being studied with the result that old accepted planting patterns are being revised better to suit the demands of certain varieties. Soil and season, however, are found to be significant in their effects slowing up changes until the case is completely proved. A new pattern needs to show very significant effects to justify the changes in machine equipment and methods that are necessarily involved.

From the array of European work and what has been done in United States and England, it seems clear that highest yields of sugar beet come from the close spacings and such spacings also give roots of highest quality. We may derive from the curves a theoretical optimum of plant populations. But this value may and does stand in decided contrast with what, because of practical considerations, is adopted.

We have seen that American practice long since refused to strain for the ultimate crop goal but was content with less than a theoretically possible yield in order to use drills, cultivators and other horse-drawn tools. It is an open question whether or not the hypothetical loss in yield of 10- to 15 percent calculated as associated with our standard procedures was an actuality, or whether the very close spacings would not, of themselves, have engendered new forms of loss not present in controlled experiments but likely to enter in field practice. DeHaan and Klijnhout pointed out that increase in plant population from 70,000 to 90,000 plants per hectare (28,340 to 36,430 per acre) meant in their experiments a gain of 6 or 7 percent, but entailed handling very many more plants smaller in size and having increased tare.

We do need to ask what fundamentally is responsible for the greater acre yields of roots and sugar and for the improved quality that comes with close spacing both of rows and of plants in the row. Obviously, the greatest yields merely mean most efficient use of field space and fertility. It will be recalled that European and American experience was positive that if row width were increased, reduction in row interval would not compensate for it. Armer's study on distribution ratios indicated the same. Clearly there is a problem of plant response here, since apparently the plant refuses to abide by arithmetic.

In most sugar beet districts of the Temperate Zone, the growing season is limited in length. Commonly the early part of the growing period is

cool and not conducive to rapid root growth, so that the soil space reached early by plant roots is limited. If the plants are wide apart, roots will only slowly permeate the space allotted. Hence closely spaced plants more completely occupy the soil space in the early half of the season than do widely spaced plants. Although soil temperatures in late April, May and early June are cool, they, along with soil moisture conditions, nevertheless are more conducive to root growth than the soil conditions of September, October and November—so much so that in many districts a lag in planting date may require nearly twice as much extension of the harvest date for equal root growth to be attained (Godard 22). A limiting factor in closeness of spacing is the length of time before interference of roots and tops of neighboring plants nullifies the early advantages. Furthermore commercial practice prescribes that roots must reach a minimum size to be marketable. If the time factor and if the slowing up of growth in the fall were not involved—were it not a matter of efficiency—then a widely spaced individual root would eventually attain a weight commensurate with the sum of weights of the closely spaced plants occupying the given surface area. The hurdle that Gerlach (20) presented, namely that to maintain yields, the average individual from a population of 40,000 plants per hectare must be 2½ times heavier than one from a population of 100,000, probably could be surmounted if, in so many places, frost did not dictate harvest.

The suggestions by Krüger (21, 26) explaining the effect of spacing on quality seem accurate. That sucrose percentages of the beet reflect the degree of ripening and that ripening occurs earlier with close spacing only hints at the basic reactions involved. The whole concept of growth of the sugar beet needs to be extended beyond this postulate. Storage of sucrose in the sugar beet must be recognized as a plant response opposed to the growth responses. A fundamental consideration in this connection is the fact that photosynthesis takes place over a far wider range of conditions, including temperature, than does growth (Coons, 9). As a result of this, sucrose percentages of the sugar beet may attain extremely high levels in California if growth is checked by the combination of high temperature and low soil moisture. In other sections of the country, cool weather conditions in the fall, accompanied usually by a low moisture content of the soil, serve to check growth allowing photosynthesis to bring about the increase of sucrose percentage in the roots from about a 12 percent level in September to 16 to 18 percent in November. In districts where rainy, mild fall weather favors growth, as at Beltsville, Maryland, a sucrose percentage of about 12 attained in September continues without much increase into October and November.

Yield and sucrose types of sugar beet differ in their responses to the major factors of the environment—the former being less sensitive to climatic and soil changes than the sugar types. The yield types, therefore, continue under early fall conditions to increase in size and remain succulent, i.e. moderate in sugar content, whereas the more sensitive sugar types

stop utilizing the elaborated carbohydrates for growth and accumulate sucrose in the roots.

It is known that nitrogen fertilizers promote growth. Krüger would explain favorable effects of close spacings as due to the ripening brought about by nitrogen depletion. He is emphasizing that a full quota of plants to the soil space utilizes more or less completely the soil nitrogen, bringing about an eventual check of growth. The low sucrose percentages associated with heavy applications of nitrogen frequently indicate improper timing and disregard of proper fertilizing practice. The proper function of nitrogen fertilizer is to produce a large plant body fully expanded over the soil space. It should be clearly understood that nitrogen must be applied early to sugar beets and certainly long before midseason. After midseason, nitrogen content of the soil should decrease so that growth may not continue at the expense of sucrose storage.

We must recognize that other factors of the environment, temperature, solar radiation, water, and soil fertility if favorable for growth may bring about utilization of carbohydrates for production of plant tissue instead of promoting sugar storage. Hence factors must be manipulated so that growth is checked in order that the products of photosynthesis may accumulate, sugar be stored in the root, and, as is said, to "ripen" the plant. One factor may not replace another, but we can magnify effects of a factor by manipulation of it and associated factors. Such advance as we may make in space adjustments will come about by proper application of the principles of plant growth.

American practice has, by compromise, accepted certain field patterns and has set up, for a given surface area, certain norms of plant population. Under our current method of culture these have effectively removed space relations from a dominant position and made yield and quality dependent upon the play of other factors principally soil fertility, culture and plant disease. Our principal depressions of yield have come from lack of stand uniformity rather than from improper space allotment. Our low levels of production reflect our failures to give the best environment for sugar beet growth.

But we now are about to enter the mechanized era of sugar beet culture. A distinguished agricultural engineer when asked how far apart the beet rows needed to be in order to give best operation of his machines said "As wide as the agronomist will let me have them." In a phrase, this puts before us the pressing problem of space relations.

We may approach the problems hopefully. If we understand and apply the basic principles, we may sometimes manipulate factors of the environment to get around apparently insurmountable difficulties. Suppose we grant that with things as they are, sugar beets grown in 30-inch rows with 8-inch spacing in the row, do not yield the same as if grown in 20-inch rows with 12-inch spacing in the row (16). Assume that it is necessary in mechanizing the job that the former be used. The agronomist

faces first an appraisal of the situation. He must decide if the advantage of the wider row warrants taking a loss, and how much. He must recognize that all districts are not climatically alike and must guard against blanket application of his findings. He may need to fit the plant to the required environment. He may try extending the growing season by early planting, he may seek by rational fertilizer practice to manipulate the intake of plant foods to promote early growth and proper balance. Sugar beet varieties differ in their reactions to space allotments, so that this phase will need to be thoroughly explored. And there remains the attack on the problem through the breeding of plants suited to mechanization. One can immediately visualize a need for a vigorously growing, large topped variety with a globe-shaped root, streamlined for easy lifting.

The new problems that face the agronomist are, therefore, not without clues for their solutions. We do not know the best way to fit the sugar beet for fully mechanized culture. The problems present a challenge to the investigator. The activities stressed in this review were chosen for a purpose—either to show the limits natural to the sugar beet, to show the physiological response of the sugar beet to space allotment, or to show a methodology of research. As the major contribution of the review, some basic physiological principles of sugar beet growth and development have been outlined as guides to plant manipulation. Application of these principles is needed for solution of the problems lying ahead. Agricultural patterns as designed for hand labor had to be changed to permit utilization of power equipment. We must now expect equally radical changes as sugar beet growing advances to fully mechanized production. It is the function of agronomic research to seek out the requirements for the improvement of practice, to appraise them, and to develop a new and successful sugar beet agriculture.

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# Effect of Spacing and Doubles on Yield of Sugar Beets in the Michigan Area

M. G. FRAKES[1]

A MAJOR QUESTION in connection with mechanized thinning of sugar beets is the effect on yields of double plants left by the thinning operation. Conclusive data are lacking in our area as to the necessity of thinning meticulously to one beet in fields planted with segmented seed. Information is needed as to the number of double or multiple hills per 100 feet of row which would decrease yields to a point where the expense of hand-thinning mechanically blocked beets would be warranted. Since weed conditions are so variable, such basic data should be obtained from a weed-free field.

The test reported here was conducted in 1946 and again in 1947. These were split-plot experiments with 4 replicated plots of each of the 16 treatments. The test was conducted in an attempt to determine how yields may be effected by a varying number of doubles and a varied spacing in the row. No attempt was made to vary the width of row since, in our area, the 28-inch row is universally used to facilitate overall farm operations.

All spacing and thinning was accurately done by hand to leave the desired number of hills and doubles. The term "double" in this test constitutes 2 beets in a 3-inch block or less. Relatively very few of the so-called doubles originated from one seed piece. All plots consisted of 4 rows 50 feet long. The two center rows were harvested for yield and analysis in all cases.

In 1946 plots were planted May 8, using 2½ pounds per acre of 7-10/64 segmented seed. Planting was done with Cobbley unit attachments on a John Deere No. 55 drill. Plots were thinned June 24 and 25 and harvested November 9 and 10. Duplicate samples were taken from each plot for sugar and purity analysis. Plots were thinned as follows: 6-inch centers with no doubles; 8-inch centers with 0, 10 and 20 percent doubles; 10-inch centers with 0, 10, 20 and 30 percent doubles; 12-inch centers with 0, 10, 20 and 30 percent doubles; 16-inch centers with 0, 10, 20 and 30 percent doubles.

Results are shown in tables 1 and 2.

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**Table 1.—Effect of spacing on yield of beets and sugar—1946.**

| Spacing | Tons beets per acre | Pounds sugar per acre |
|---|---|---|
| 6-inch | 9.54 | 3162 |
| 8-inch | 12.14 | 3930 |
| 10-inch | 12.52 | 4098 |
| 12-inch | 12.89 | 4182 |
| 16-inch | 12.72 | 4106 |

Table 2.—Effect of doubles on yield of beets and sugar—1946.

| Percent doubles | Tons beets per acre | Pounds sugar per acre |
|---|---|---|
| 0 | 12.47 | 4028 |
| 10 | 12.48 | 4059 |
| 20 | 12.64 | 4106 |
| 30 | 11.89 | 3887 |

The effect of spacing on yield of roots and indicated available sugar was not significant except for the 6-inch spacing which was significantly lower.

The effect of doubles on yield of roots and indicated available sugar was not significant with any treatment.

In 1947, plots were planted May 31 using 3½ pounds per acre of 7-10/64 segmented seed. Planting was done with Cobbley unit attachments on a John Deere No. 55 drill. Plots were thinned June 27 and harvested October 21. Duplicate samples were taken from each plot for sugar and purity analysis. Plots were thinned as follows: 10-inch spacing with 0, 10, 20 and 30 percent doubles; 12-inch spacing with 0, 10, 20 and 30 percent doubles; 16-inch spacing with 0, 10, 20 and 30 percent doubles; 20-inch spacing with 0, 10, 20 and 30 percent doubles.

Results are shown in tables 3and 4.

Table 3.—Effect of spacing on yield of beets and sugar—1947.

| Spacing | Tons beets per acre | Pounds sugar per acre |
|---|---|---|
| 10-inch | 8.21 | 2190 |
| 12-inch | 8.21 | 2119 |
| 16-inch | 8.83 | 2163 |
| 20-inch | 8.52 | 2109 |

Table 4.—Effect of doubles on yield of beets and sugar—1947.

| Percent doubles | Tons beets per acre | Pounds sugar per acre |
|---|---|---|
| 0 | 8.50 | 2113 |
| 10 | 8.81 | 2236 |
| 20 | 8.54 | 2208 |
| 30 | 7.93 | 2024 |

There were no significant differences in yield of beets or indicated available sugar caused by any treatment.

# What Is the Practical Spacing Pattern For Sugar Beets Grown in the Red River Valley, Minnesota Area?

A. W. Skuderna[1]

A LARGE AMOUNT of work has been done on space relationship between beet plants, population and distribution studies with sugar beets, effect of single- and multiple-beet hills on yields, effect of variety and soil-fertility levels upon space requirements, and effect of environment on beet populations. Practically all of these studies have been conducted with beets thinned in normal manner, with little or no mechanization involved, either in cross-blocking or in cross-cultivating the field, or in strictly mechanical thinning. In the Agronomy section of The American Society of Sugar Beet Technologists, several papers were presented on this subject and are printed in the 1946 Proceedings, pages 154-184, inclusive. With few exceptions in the irrigated areas, the highest sugar-per-acre yields, quality stressed, were obtained from acre populations in excess of 20,000 beets per acre uniformly distributed in the row, and with row widths averaging 20 to 22 inches.

Experimental tests conducted by Immer (2)[2] in the Red River Valley, Minnesota, area, with acre populations ranging from 12,960 beets to 24,502 beets in row spacings of 22 to 16 inches, reported increased yields from the higher acre populations. Similar results were obtained by Doxtator and Skuderna (1) from experiments conducted in the same area, with the higher yields coming from the 12- and 15-inch spacings in the row, and row width plantings 18 inches apart.

Field tests involving width of row plantings and spacing of beets in the row have been conducted in this non-irrigated area for more than 20 years. The general trend of results supports the present practice of planting sugar beets in 18-inch row widths, and then cross-blocking them on 18-inch centers, thus making an 18 by 18-inch pattern, which lends itself well to cross-cultivation. In years of more generous rainfall, higher populations per acre than those obtained from this spacing pattern can be profitably supported. Considering, however, that this is a marginal rainfall area, where the annual precipitation averages below 20 inches, moisture limitations dictate the acre population of beets which can be maintained. Generally, 18,000 beets per acre are obtained after thinning, resulting in a harvest stand of about 16,000 beets per acre. With the rapid changes brought about by mechanization in methods of growing, thinning, hoeing and

[1]General Agriculturist, American Crystal Sugar Company.
[2]The numbers in parentheses refer to literature cited.

harvesting beets, changes in row width and spacing in the row for this area seem warranted.

Beginning with 1930 and extending over an 8-year period, field comparisons were made between cross-blocked and hand-blocked beets, with approximately the same acre populations. The results obtained were very much in favor of the cross-blocked beets, indicating the value of a more uniform distribution of plants in the row, the beets being of more even size, and fields much cleaner than in the hand-blocked fields.

From 1938 to 1946, field tests were continued to determine the value of cross-cultivating for purpose of maintaining a soil mulch, preventing cracking of soil and loss of soil moisture thereby, and a more effective control of weeds. A total of 193,204 acres of beets was involved in these comparisons, of which 140,268 acres were cross-cultivated, 11,208 acres cross-blocked only, and 41,728 acres hand-blocked. All fields were hand-thinned. Practically the entire acreage was planted in 18-inch width rows, the cross-blocked and cross-cultivated acreage being cross-blocked on 18-inch centers; the hand-blocked beets were spaced 12 to 14 inches in the row resulting in about an 8 per cent higher population in after-thinning stands but less than 3 percent more beets at time of harvest than those obtained from either the cross-cultivated or cross-blocked acreage. The results obtained are as follows:

**Table 1.—Average yield tons beets per acre obtained in Red River Valley, Minnesota, area, years 1938-1946, inclusive.**

| Year | Cross-cultivated beets (tons) | Cross-blocked beets (tons) | Hand-blocked beets (tons) |
|---|---|---|---|
| 1938 | 9.30 | 8.32 | 8.79 |
| 1939 | 9.38 | 8.31 | 8.68 |
| 1940 | 10.56 | 9.08 | 10.49 |
| 1941 | 12.19 | 12.06 | 11.51 |
| 1942 | 12.59 | 13.12 | 12.04 |
| 1943 | 10.10 | 10.05 | 9.05 |
| 1944 | 12.44 | 11.26 | 11.04 |
| 1945 | 10.46 | 11.29 | 9.42 |
| 1946 | 11.19 | 10.68 | 10.68 |
| Averages | 10.91 | 10.46 | 10.19 |
| Number of acres | 140,268 | 11,208 | 41,728 |

The results obtained from this 9-year comparative study strongly emphasize the need of maintaining a soil mulch between beets. Any change-over from present practice to full mechanization must take cognizance of this factor as it is of paramount importance to successful beet growing in this area. It is worthy of note that in each of the 9 years the cross-cultivated acreage outyielded the hand-blocked acreage by fairly substantial margins, the over-all average difference amounting to .72 ton beets per acre or about a 7-percent increase yield in favor of this practice.

Anticipating possible changes in row widths and also spacing between beets in the row, experimental work was undertaken on this phase of investigation in 1939 and continued to the present time. It is of interest

to note (table 2) that in 1939, a year of less than 18 inches precipitation, the trends in results were the same as those obtained in 1941 when fully 50 percent more total precipitation was had.

**Table 2.—Comparison of row widths holding spacings in the row constant, East Grand Forks, Minnesota.**

| Spacing (inches) | Tons beets per acre | Percent sucrose | Pounds sugar per acre |
|---|---|---|---|
| | **Year 1939** | | |
| 18x15 | 9.85 | 17.08 | 3,365 |
| 22x15 | 9.96 | 16.97 | 3,380 |
| 26x15 | 9.37 | 16.44 | 3,081 |
| 30x15 | 9.44 | 16.20 | 3,059 |
| | **Year 1941** | | |
| 18x15 | 12.67 | 15.12 | 3,831 |
| 22x15 | 13.82 | 15.08 | 4,168 |
| 26x15 | 12.79 | 14.83 | 3,794 |
| 30x15 | 11.86 | 14.61 | 3,465 |

Increasing the row width beyond 22 inches generally depressed not only tonnage yields of beets but also the sucrose percentage in the beet. While changes in width-of-row planting may be necessary to avoid crowding effects on beet rows because of heavy equipment usage, and to accommodate a program of mechanizing fully the spring, early summer and fall operations in the beet field, it is apparent from results obtained to date that row widths should not exceed 22 inches and preferably remain at 18 inches until such time as more information is accumulated on mechanical thinning to warrant a change to wider rows.

Beginning with 1942, experiments on varying the row widths and the spacing of beets in the row were undertaken to determine the effect of these variables upon tonnage yield of beets and percentage of sucrose in the beet. The combined results from a 5-year test, 1942 to 1946, inclusive (table 3), in which tests approximately the same soil area per beet block was maintained, the following trends were observed:

**Table 3.—Comparison of row width and spacings within the row combined results years 1942 to 1946, inclusive, Red River Valley, Minnesota, area.**

| Soil area per beet block (square inches) | Spacing pattern (inches) | Tons beets per acre | Percent sucrose in beet | Pounds sugar per acre |
|---|---|---|---|---|
| 324 | 18x18 | 10.64 | 15.90 | 3,365 |
| 330 | 22x15 | 11.63 | 15.89 | 3,688 |
| 312 | 26x12 | 10.19 | 16.02 | 3,265 |
| 300 | 30x10 | 9.61 | 15.78 | 3,042 |

The results favor the 22-inch width row with a 15-inch spacing of beets within the row. Increasing row widths beyond that point and reducing spacings within the row so as to maintain equal acre populations of beets did not result in an improvement of yields of beets or in pounds sugar per acre.

## Discussion

Tests conducted in the Red River Valley area over a 20-year period definitely point to the most productive use of a width row planting not exceeding 22 inches. Present mechanization trends may dictate a change from the conventional 18-inch row width planting and possibly also a change in present spacing width between beets in the row. Preliminary tests conducted in 1947 with 20- and 22-inch width row plantings in which three 16-inch and five 14-inch spacings between beets in the row were employed, cross-blocked and cross-cultivated, produced satisfactory tonnage yields and sucrose percentage in the beet in both hand and fully mechanical thinning. It is quite obvious from results obtained that the type of spacing pattern employed has a considerable influence on more effective utilization by the plant of the feeding area in the soil. A 15-inch average spacing between beets (such as results from a combination of 16-inch and 14-inch spacing in the row to accommodate tractor wheels and efficient use of tools for cross-cultivating) gives every indication of being the best spacing for this area, providing row widths do not exceed 22 inches apart between beet rows. All of the work reported herein is on spacings in the row in which beet-containing-blocks ranged from 3 inches to 4½ inches in width. This width block is entirely too wide for strictly mechanical thinning in which 1½-inch wide blocks are to be employed. Therefore, definite recommendations for a wider width row than the present 18-inch planting must necessarily await the outcome of planned large-scale field tests in 1948. One fact is certain; namely, sugar-per-acre yields for this area are sharply reduced when row width plantings more than 22 inches apart are employed.

## Summary and Conclusions

Comparative field tests conducted over a 9-year period in the Red River Valley, Minnesota, area have conclusively shown the value of cross-blocking and cross-cultivating beets, the average increases being .27 ton and .72 ton more beets per acre, respectively, than were obtained from hand-blocked beets. These comparisons were made on 193,204 acres of beets, all of which were hand thinned.

Width-of-row spacings beyond 22 inches apart conclusively show a reduction in tonnage yield of beets per acre, and a depressed sucrose percentage in the beet regardless of spacing within the row.

Spacing patterns approaching a square pattern are apparently more productive of more efficient utilization by the plant of the soil feeding area.

With a change from hand thinning to mechanical thinning, and use of mechanical beet harvesters, a change from present 18-inch row width planting may be dictated, but not to exceed 22-inch width row planting.

The spacing within the row which gives promise is a 16-inch and 14-inch combination; 16-inch spacings between beets in the row to provide sufficient space between beets to permit tractor wheel travel in cross-cultivation, and

14-inch spacings between the tractor wheels so as to maintain the acre population of beets near the 20,000 mark. Regardless of spacings used, these must be sufficiently wide to permit cross-cultivation for conservation of moisture, maintenance of soil mulch to prevent checking of soil, and for effective control of weeds. Further large-scale field tests are planned for strictly mechanical thinning of beets in 1½-inch blocks instead of the customary 3- to 4½-inch width block presently employed in hand thinning. With the establishment of these narrower blocks at time of cross-blocking to make effective mechanical thinning possible, and widespread use of 2-row beet harvesting equipment in 1948, information will be forthcoming shortly relative to a change, if any, in the present 18-inch row width planting practice for this area.

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# Sugar Beet Yields From Varying Row Spacings and Acre Populations

C. W. Doxtator[1]

Preliminary tests conducted at Rocky Ford, Colorado, in 1945, on 20-inch and 30-inch width beet rows, with equal acre populations, gave yield results significantly in favor of the narrower row. Since beet plantings in rows wider than 30 inches are not likely to be generally made, an experiment was set up in 1946 to determine what yield differences would be obtained from plantings of 20-, 24- and 28-inch row widths; and at acre beet-population levels of 22,000, 26,000, and 30,000. This paper reports the results obtained from this experiment for the 2-year period 1946-47.

## Experimental Procedure

The 3-row spacings at three population levels, providing nine variables, were set up as a randomized-block experiment, and 6 replications of plots of each variable were planted in each of the 2 years. Plots were 6 rows wide by 40 feet long. American No. 3 segmented beet seed, germinating above 85 percent, was used both years. The seed was planted at a rate of 5.2 pounds per acre in 1946, and in 1947 at 6.0 pounds per acre. At thinning time, a long measuring stick, with the beet spacing distance for each plot indicated on the stick by use of thumb-tacks, was used to obtain the correct spacing distance between beets in the row. Long hoes were used for blocking and short-handle, narrow hoes for thinning. After thinning, stand counts were obtained. At harvest all marketable beets from 36 feet of row, from each of the two center rows of each plot, were taken for yield data. Only beets weighing more than .33 pound were considered marketable. Sucrose percentage data were obtained from the analysis of 2 samples of 15 marketable beets each, from each plot.

Since the tests conducted each year were identical in plot lay-out, and planted on fields less than 1 mile apart, the data obtained are reported as a 12-replicate test for the 2-year period.

## Experimental Results

Table 1 gives the acre populations planned for, those obtained, and the distribution pattern of the beets.

The beet stand obtained in both years was not quite adequate to permit populations of 30,000 beets per acre in the 24- and 28-inch rows. In 1946, shallow planting along with dry top soil, resulted in low and erratic stands, and in 1947 severe crusting of surface soil occurred which reduced the emerging stand of beets. Some loss of beets occurred after

[1]Plant Breeder, American Crystal Sugar Company, Rocky Ford, Colorado.

thinning due to root diseases; and these losses, along with beets smaller than marketable size further reduced stands, as shown by the marketable beets harvested. The greatest average loss between thinning date and harvest occurred in the widest row spacing.

**Table 1.**—Beet spacing pattern, along with acre populations planned for, and obtained. Average 1946-47.

| Treatment No. | Acre population wanted | Distribution pattern in inches | Thinned acre population obtained | Marketable beets | |
|---|---|---|---|---|---|
| | | | | Total per acre | Percent of thinned stand |
| 1 | 21,994 | 20x14.26 | 21,334 | 20,634 | 96.9 |
| 2 | 22,022 | 24x11.88 | 22,052 | 21,015 | 95.3 |
| 3 | 22,009 | 28x10.18 | 21,496 | 20,341 | 94.6 |
| 4 | 26,006 | 20x12.06 | 25,720 | 24,748 | 96.2 |
| 5 | 26,006 | 24x10.05 | 25,096 | 23,346 | 93.0 |
| 6 | 25,984 | 28x 8.62 | 24,469 | 23,045 | 94.2 |
| 7 | 30,013 | 20x10.45 | 29,279 | 28,467 | 97.2 |
| 8 | 30,013 | 24x 8.71 | 27,593 | 25,542 | 92.6 |
| 9 | 29,983 | 28x 7.41 | 25,130 | 22,743 | 90.5 |

The yield results obtained in the experimental test are given in table 2.

**Table 2.**—Yield of beets in tons and sugar in pounds per acre with sucrose percentage, from beets planted in 3-row spacings at three different population levels. Average 1946-47.

| Treatment No. | Distribution pattern of beets to allow an acre population of: | Row spacing | Tons beets per acre | Sucrose percent | Gross pounds sugar per acre |
|---|---|---|---|---|---|
| 1 | | 20 | 18.62 | 14.06 | 5226 |
| 2 | 22,000 (low) | 24 | 17.88 | 14.00 | 5011 |
| 3 | | 28 | 16.97 | 14.21 | 4830 |
| 4 | | 20 | 18.66 | 14.30 | 5322 |
| 5 | 26,000 (medium) | 24 | 17.39 | 14.24 | 4950 |
| 6 | | 28 | 17.27 | 14.30 | 4941 |
| 7 | | 20 | 18.66 | 14.58 | 5451 |
| 8 | 30,000 (high) | 24 | 17.46 | 14.26 | 4974 |
| 9 | | 28 | 16.47 | 14.44 | 4749 |
| General mean | | | 17.70 | 14.27 | 5050 |
| Significant differences (odds 19:1) | | | 1.54 | .74 | 501 |

The yield of beets per acre was higher from 20-inch rows than from either the 24- or 28-inch rows at each of the three levels of population, and significantly higher than the 28-inch rows in the "low" and "high" acre populations. The average beet yield of the 20-inch row spacing, considering all three populations (treatments 1, 4, 7) as compared with similar averages for the 24-inch and 28-inch spacings, shows a significant increase in yield in favor of the narrow row spacing.

Sucrose percentage differences in this test did not quite reach the 5 percent level of significance; nevertheless there is a definite trend in favor of higher sucrose in the higher acre populations.

In sugar per acre, the highest yield was obtained from the high acre population (28,467 beets) planted in 20-inch rows. This figure is significantly higher than the sugar yields from 28-inch rows at all three population levels, as well as 24-inch rows at the medium population level.

## Discussion

The results of this experiment indicate that the distribution pattern affected the yield of beets. Yields per acre of beets and of sugar were highest for rows spaced 20 inches apart at each of the three acre-population levels. In sucrose percentage, no significant differences were found, but a trend toward higher sucrose from higher acre populations, regardless of row width, was observed. These results are in general agreement with the earlier investigations of Skuderna, et. al. (3),[2] and Brewbaker and Deming (1), and with more recent reports of Tolman (4), and Doxtator and Skuderna (2).

One of the main difficulties encountered in this experiment was that of obtaining high acre-beet populations from row spacings wider than 20 inches (table 1). Where 30,000 beets per acre were required, the thinned stand obtained from 24-inch rows and 28-inch rows was less than from 20-inch rows by 1,686 and 4,149 beets, respectively. This lack of stand is explained by the inadequate and non-uniform emergence of the beet plants. Further, the loss of harvested beets was greater in the 24- and 28-inch rows than in the 20-inch rows because of a higher percentage of beets smaller than marketable size.

Considering that earlier investigations of acre beet populations have shown that 25,000 to 35,000 beet plants per acre are more generally productive of high sugar yields than lesser populations, it would appear most advantageous to maintain relatively high populations per acre regardless of the width of the beet row. However, to obtain the acre population which gave the highest yield in this experiment it would be necessary, in 28-inch rows, to space the beets less than 8 inches apart. This is a much more difficult task for hand labor or for mechanical thinning machines than to space beets 10.5 inches in 20-inch row plantings to obtain the same acre population.

Wider row spacings do have the advantages of reducing mileage travel of drills, cultivators, and other row machines, and of more easily accommodating the large and heavy beet harvesters of the present day. However, the data from this experiment indicate that in this area the obtaining of adequate beet stands was increasingly difficult in wide rows; and with less than adequate acre populations sugar-per-acre yields were significantly lowered. Even at the low and medium acre-population levels where similar numbers of beets were obtained for all three spacings, there was a consistent trend toward low beet tonnage and sugar-per-acre yields with wider row spacings.

## Summary

Replicated plot tests in 1946 and 1947 near Rocky Ford, Colorado, of 20-inch, 24-inch, and 28-inch row spacings, at each of three acre-population levels, resulted in a definite trend toward lower yields of sugar per

[2]The numbers in parentheses refer to literature cited.

acre with increased widening of beet rows. Significantly lower sugar-per-acre yields were obtained from the 28-inch row width at all three acre-population levels, and a significantly lower sugar-per-acre yield from the 24-inch row spacing at the medium acre-population level, than from the 20-inch row spacing at the high acre-population level.

Sucrose percentage in marketable beets was higher from the higher acre-beet populations, but did not quite reach the significant level. Width of row did not affect sucrose percentage appreciably in this experiment.

Difficulty was experienced in obtaining a stand of 30,000 beets per acre, in spite of adequate planting rates of seed high in germination, and with careful thinning methods. This difficulty was greatest in the 28-inch row spacing.

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# The Effect of Variations in Row Width and Plant Populations on Root Yields and Sucrose Percentage of Sugar Beets at Fort Collins, Colorado[1]

G. W. Deming[2]

In a replicated experiment sugar beets were grown in 12-, 20-, 22-, 24-, 30-, and alternate 20- and 40-inch rows. Plant populations were varied by spacing beets 12 inches apart in each row width. In addition, some plant populations were held constant by varying the spacing in certain of the row widths. Twenty-inch rows with plants spaced 12 inches in the row were used as the check treatment. The results of this experiment are summarized in table 1. In no case were there significantly different yields from

**Table 1.**—Acre yields of roots, sucrose percentage and gross sugar production as obtained in width of row and sugar beet population study. The inside 4 rows of 8-row plots were harvested. Fort Collins, Colorado, 1947. (Data given as 8-plot averages.)

| Treatment | | | | Acre yields | | |
|---|---|---|---|---|---|---|
| No. | Row width (inches) | Plant spacing in row (inches) | Population[1] per acre (plants) | Roots (tons) | Gross sugar (pounds) | Sucrose (percentage) |
| 1. | 12 | 12 | 43,560 | 14.50 | 3706 | 12.78 |
| 2. | 20 | 12 | 26,136 | 16.02 | 4035 | 12.60 |
| 3. | 20 | 7.2 | 43,560 | 14.91 | 3769 | 12.62 |
| 4. | 22 | 12 | 23,760 | 15.44 | 3843 | 12.48 |
| 5. | 22 | 10.9 | 26,150 | 15.20 | 3649 | 11.99 |
| 6. | 24 | 12 | 21,780 | 15.14 | 3541 | 11.75 |
| 7. | 24 | 10 | 26,136 | 14.67 | 3529 | 12.02 |
| 8. | 24 | 12 | 26,136[2] | 14.60 | 3680 | 12.65 |
| 9. | 30 | 12 | 17,424 | 13.92 | 3368 | 12.08 |
| 10. | 30 | 8 | 26,136 | 13.82 | 3398 | 12.29 |
| 11. | Alt. 20 and 40 | 12 | 17,424 | 13.48 | 3146 | 11.71 |
| 12. | Alt. 20 and 40 | 12 | 20,900[2] | 12.87 | 3012 | 11.76 |
| General mean of test | | | | 14.55 | 3556 | 12.23 |
| F value | | | | 5.61** | 7.45** | 2.23* |
| 2 x the S. E. of a Diff. (Odds of 19:1) | | | | 1.07 tons | 301 pounds | 0.74% |
| S. E. of mean in percentage of general mean | | | | 2.59% | 2.99% | 2.14% |

[1]The actually attained populations in the thinned stands of these treatments were reasonably close approximations of the theoretical populations as given in this table.
[2]Populations per acre attained by 10 percent blank, 65 percent 1-plant, 20 percent 2-plant and 5 percent multiple-plant hills.

different populations grown in the same row width. An excessive plant population of 43,560 plants per acre (12- x 12-inch and 20- x 7.2-inch spacings) yielded less than the check; the differences in root yield being just significant at odds of 19:1. In general root yields, sucrose percentages, and gross sugar yields declined as row widths increased from 20 inches. Root yields from both the populations grown in 22-inch rows and from

[1]Experiments conducted in cooperation with Colorado Agricultural Experiment Station.
[2]Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture. Colorado Agricultural Experiment Station Scientific Series Paper No. 259.

one of the three populations grown in 24-inch rows were not significantly below the yield of the check. Root yields from both the populations grown in the alternate 20- and 40-inch rows were below the yields from populations grown in 30-inch rows; the larger of these differences being just short of significance. Sucrose percentages in the beets from the excessive populations were slightly, but not significantly, higher than sucrose percentage of the check. Under the conditions of this test, the lowest yield of gross sugar from any of the five populations grown in 22- or 24-inch rows was about 500 pounds per acre less than the yield of the check. It is possible that convenience of operation of machinery and actual savings in travel time for cultural operations would compensate for such reductions in yield.

# Row Widths and Sugar Beet Production

Bion Tolman, Ronald Johnson, A. J. Bigler[1]

In recent years there has been a growing tendency among sugar beet growers both to widen row widths and to increase the spacing between beets within the row. The tendency to widen the spacing of beets within the row has no doubt resulted from the fact that increased spacing speeds both the hand-thinning and hand-topping operation. Increased row width spacing has largely developed along with the development and use of mechanical harvesting equipment. Most of the harvesting equipment in present use harvests one row at a time, and a reduction of the number of rows per acre has great appeal to the operator of this type of harvesting equipment. There is also a general feeling that rows should be wider than 20 inches for machines and power equipment to operate most efficiently.

The above considerations were largely responsible for the row width and spacing studies which have been conducted during the past 3 years in the mountain states area. The main purpose of these tests has been to investigate the effect of increased row widths on production and to find out whether the spacing between beets within the row should be decreased as spacing between the rows is increased.

## Experimental Methods and Procedures

All the row width and spacing tests utilized a split plot design. Each row width plot was 8 rows wide and 400 to 800 feet long. These strips were then divided into three or four sub-plots to accommodate the within-the-row spacing treatments. This made each sub-plot 8 rows wide and approximately 200 feet long. The four center rows of each 8-row plot were weighed for the yield record, so that the yield record from each sub-plot was based on the weight of beets from 500 to 600 feet of row. The sugar analysis made on each plot was based on two 10-beet samples. In each test there was a minimum of four replicated plots of each treatment, and in the 1946 and 1947 tests there were six replicated plots of each treatment. Row widths tested varied for each of the 3 years, and the treatments are apparent from the various tables in which the experimental results are presented.

## Tests in 1945

The row width and spacing tests conducted at Granger, Utah, in 1945 included a comparison of 20-, 26-, 32- and 38-inch row widths, and on each row width 8-, 10-, 12- and 15-inch spacing of beets within the row was compared. A general view of this plot is shown in figure 1, and the complete set of treatments and the data for each treatment are given in table

[1]Research Director and Research Assistants, Utah-Idaho Sugar Company. The entire production staff helped carry through the cooperative tests reported here.

1. It is evident from the data that maximum yield of beets per acre and maximum yield of sugar per acre were produced on 20-inch rows with 12-inch spacing of beets within the row. Increasing spacing within the row and increasing the spacing between rows decreased both tonnage and the sucrose content of the beets produced. There was a decrease of from 600 to 800 pounds of sugar per acre as row width was widened from 20 to 26 inches, and the loss of sugar per acre approached 2,000 pounds, or 20 to 25 percent of the yield on 20-inch rows as the row width was widened to 38 inches.

Figure 1.—General view of row width plot, Granger, Utah, 1945. This section of the plot shows a contrast of the 20-inch rows with the 38-inch rows. Final yield for the 20-inch rows was 29.1 tons per acre as compared with 25.6 tons per acre on the 38-inch rows. Some of the various within-the-row spacing treatments are apparent from the differences in density of population which account for the square-shaped block effects.

It is also very evident from the data that optimum spacing within the row remained more or less constant regardless of row width. This fact indicates that distribution of beets per acre is more important than number of beets per acre. A distribution approaching a square, such as 12-inch spacing on 20-inch rows, was much more efficient than where the space allotment per beet was extremely rectangular in shape as was obtained with 8-inch spacing on 38-inch rows. Under the conditions of this test, 12-inch spacing of beets within the row gave maximum yields.

A more complete presentation and discussion of these data have been previously reported (5).[2]

[2]The numbers in parentheses refer to literature cited.

**Table 1.**—Effect of row width and spacing of beets within the row on the yield and sucrose content of sugar beets grown at Granger, Utah, 1945.

| Spacing in row | Row widths as indicated | | | | Average for spacing in the row |
|---|---|---|---|---|---|
| | 20 inches | 26 inches | 32 inches | 38 inches | |
| 8-inch spacing | | | | | |
| Beets per acre | 36,540 | 29,136 | 24,560 | 20,253 | 27,622 |
| Tons per acre | 28.48 | 26.14 | 25.56 | 25.35 | 26.38 |
| Sucrose percentage | 17.24 | 16.78 | 16.24 | 16.16 | 16.60 |
| Gross sugar per acre | 4.910 | 4.374 | 4.149 | 4.096 | 4.382 |
| 10-inch spacing | | | | | |
| Beets per acre | 30,697 | 24,774 | 20,807 | 16,639 | 23,229 |
| Tons per acre | 28.26 | 26.89 | 26.48 | 25.24 | 26.72 |
| Sucrose percentage | 17.15 | 16.75 | 16.28 | 15.93 | 16.53 |
| Gross sugar per acre | 4.844 | 4.500 | 4.315 | 4.015 | 4.418 |
| 12-inch spacing | | | | | |
| Beets per acre | 25,784 | 20,938 | 16,090 | 13,862 | 19,168 |
| Tons beets per acre | 30.07 | 28.40 | 26.98 | 25.76 | 27.80 |
| Sucrose percentage | 16.98 | 16.41 | 15.98 | 15.78 | 16.29 |
| Gross sugar per acre | 5.106 | 4.665 | 4.312 | 4.060 | 4.536 |
| 15-inch spacing | | | | | |
| Beets per acre | 21,010 | 16,636 | 12,312 | 10,626 | 15,146 |
| Tons per acre | 29.50 | 28.48 | 25.76 | 26.25 | 27.50 |
| Sucrose percentage | 16.60 | 16.20 | 15.61 | 15.18 | 15.90 |
| Gross sugar per acre | 4.901 | 4.614 | 4.019 | 3.975 | 4.377 |
| Average for row widths | | | | | |
| Beets per acre | 28,508 | 22,871 | 18,442 | 15,345 | |
| Tons per acre | 29.08 | 27.48 | 26.20 | 25.65 | |
| Sucrose percentage | 16.99 | 16.54 | 16.03 | 15.76 | |
| Gross sugar per acre | 4.940 | 4.538 | 4.199 | 4.036 | |

Replicated test with four replications of each treatment.

## Tests in 1946

The decrease in yield in the 1945 test was so rapid as row width was increased that further tests were conducted in 1946 to investigate a much smaller variation in row widths and to determine whether yields could be increased by increasing the number of rows per acre through the use of wide and narrow row width combinations. Row widths studied included a 12-20-inch wide and narrow combination, 20-inch rows, and 24-inch rows. Three variations on spacing within each row width were compared. These within-the-row spacing comparisons were 9.5 inches, 12 inches, and 16 inches. Maximum yields were again obtained with 12-inch spacing within the row, and there was no indication that as row width was increased that there was any advantage in spacing the beets closer than 12 inches in the row.

The detailed data on within-the-row spacing are not presented inasmuch as it can be summarized by stating that within the limits of 75 to 125 beets per 100 feet of row, there were no significant differences in either yield or sucrose content.

Row width, however, did have a significant effect on the yield of both beets and gross sugar per acre. A summary of the row width data for 1946 is given in table 2. Yields decreased when row widths varied either way from 20 inches. Increasing row widths from 20 inches to 24 inches resulted in a decrease of sugar per acre as follows: Washington 790 pounds; Idaho 1,332 pounds; South Dakota 250 pounds; and Utah 676 pounds. If this loss in sugar per acre is projected over the entire acreage harvested by farmers

under contract to the Utah-Idaho Sugar Company in 1947, the total loss in sugar would be in excess of 75,000,000 pounds or 750,000 bags of sugar, and this sugar would have a cash value of approximately $7,500,000.

**Table 2.**—Effect of row width on the yield and sucrose content of sugar beets grown in four western states in 1946.

| Location of tests | Tons of beets per acre | | | Sucrose percentage | | | Tons gross sugar | | |
|---|---|---|---|---|---|---|---|---|---|
| | 12-20 inch comb. | 20-inch rows | 24-inch rows | 12-20 inch comb. | 20-inch rows | 24-inch rows | 12-20 inch comb. | 20-inch rows | 24-inch rows |
| Washington | 27.23 | 30.02 | 27.66 | 15.78 | 15.72 | 15.63 | 4.297 | 4.718 | 4.323 |
| Idaho | 23.82 | 25.52 | 21.35 | 17.30 | 17.50 | 17.80 | 4.121 | 4.466 | 3.800 |
| South Dakota | 10.96 | 12.73 | 12.44 | 17.00 | 17.30 | 16.70 | 1.863 | 2.202 | 2.077 |
| Utah | 26.43 | 28.47 | 26.48 | 14.01 | 13.70 | 13.45 | 3.703 | 3.900 | 3.562 |
| Average | 22.11 | 24.18 | 21.98 | 16.02 | 16.05 | 15.90 | 3.496 | 3.821 | 3.441 |

## Tests in 1947

As a result of the 1946 tests, interest in the 1947 tests was centered around various wide and narrow row width combinations, which would average the equivalent of 20- to 22-inch rows. The complete set of row widths tested is listed in table 3. The data from the two 1947 tests indicate that uniform width rows 20 inches apart produced higher yields than did any of the wide and narrow combinations averaging 20 inches. The data also support all previous data which indicated a loss in production on all row widths wider than 20 inches. The 20-inch rows produced an average of 504 pounds more gross sugar per acre than the next closest row width treatment. These tests indicated that wherever possible 20-inch rows should continue to be the standard row width, and that where a change is necessary to adjust to machines and power equipment, the next best row widths from the standpoint of maintaining production would be one of the following: 18-24-inch or 20-22-inch wide and narrow combinations, or straight 22-inch.

**Table 3.**—Effect of various row widths and row width combinations on the yield and sucrose content of sugar beets as shown by tests in Utah and Idaho—1947.

| Row widths tested | Tons of beets per acre | | | Sucrose percentage | | | Tons gross sugar | | |
|---|---|---|---|---|---|---|---|---|---|
| | Utah | Idaho | Average | Utah | Idaho | Average | Utah | Idaho | Average |
| 16-22-inch combination | 19 | 26.48 | 19.50 | 22.99 | 13.00 | 18.90 | 15.95 | 3.450 | 3.686 | 3.568 |
| 16-24-inch combination | 20 | 26.15 | 19.49 | 22.82 | 13.10 | 18.84 | 15.97 | 3.426 | 3.674 | 3.550 |
| 18-22-inch combination | 20 | 27.76 | 20.08 | 23.92 | 12.86 | 18.87 | 15.87 | 3.454 | 3.791 | 3.623 |
| 18-24-inch combination | 21 | 27.58 | 19.81 | 23.70 | 12.97 | 18.86 | 15.92 | 3.584 | 3.733 | 3.659 |
| 20-inch rows | 20 | 29.96 | 20.43 | 25.20 | 13.29 | 18.75 | 16.02 | 3.987 | 3.834 | 3.911 |
| 22-inch rows | 22 | 28.16 | 19.01 | 23.59 | 13.18 | 18.40 | 15.79 | 3.716 | 3.497 | 3.607 |
| 20-22-inch combination | 21 | 26.70 | 19.77 | 23.24 | 13.10 | 18.82 | 15.96 | 3.504 | 3.716 | 3.610 |
| 20-24-inch combination | 22 | 26.73 | 18.39 | 22.56 | 12.93 | 18.61 | 15.77 | 3.437 | 3.421 | 3.429 |

## Discussion and Summary

One of the fundamental objectives of sugar beet production is to establish the industry so that both the farmer and the processor can make a consistent, profitable cash return on the capital and labor which they invest. Some of the factors on which the attaining of the above objective depends are:

1.—High production per acre of high-quality beets.
2.—Low production costs per ton of beets produced.
3.—Full assurance that the crop can be produced by the combined use of hand and machine labor.

When these three fundamentals have been assured, the industry will likely find the stabilization which it so much desires.

Any program which would achieve this goal must give due consideration to all three of the above factors. We might attain complete mechanization and still be handicapped by high production costs, or a low level of production combined with decreased quality.

Data presented in this paper indicate that row width is one of the factors which has an influence on both the level of production and the quality of the beets produced. In all tests, maximum yields of both beets and sugar per acre resulted from 12-inch within-the-row spacing on 20-inch rows. Other tests conducted in the mountain and inter-mountain area support these results (1) (2) (3) (4).

It is recognized that row widths must be wide enough to permit the use of machines and power equipment. It is felt, however, that thought should be given to adapting machines and power equipment to those row widths which will maintain, as near as is possible, maximum production.

More careful attention to field layout, and doing a precision job of drilling will facilitate the use of machines on the narrower row widths. In many cases where machines have had difficulties on 20-inch rows, most of the difficulty has occurred because of crooked rows and because of guess-rows, which in many places were narrower than 20 inches.

In no case should farmers in the mountain states widen row widths more than is absolutely necessary to make it possible to successfully operate their power equipment.

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# Recent Experimental Results of Row Spacings and Field Population Of Sugar Beets

R. J. TINGLEY[1]

DURING THE 1947 season two separate, but practically identical, tests were conducted in Kern County, California, to determine the variation in yield and sugar content that would result from three different "in-the-row" spacings of beets planted in rows 30 inches apart. The planting was made with decorticated seed at a little over 3 pounds per acre, and the beets were thinned on March 25 and 26.

Test 1 consisted of 15 replications, of two rows each, at three different spacings in the row. Rows were approximately 1,250 feet long. Treatment (a) was thinned to leave single beets 6 inches apart, treatment (b) 8 inches apart and treatment (c) 10 inches apart. Actual counts after thinning resulted in the following average numbers of beets per 100 feet of row: Treatment (a) — 198; (b) — 153; (c) — 127. Test 2 consisted of 15 replications of three rows each, approximately 800 feet long. With the same spacing used for test 1 the actual counts after thinning showed average stands for treatment (a) — 197, (b) — 148, and (c) — 118. The field work was very carefully done and there were practically no doubles in any of the plots.

All plots received 400 pounds of 17-7-0 fertilizer as a side dressing after thinning and also about 175 pounds of anhydrous ammonia in two applications of irrigation water. All cultural operations on both tests were timely and exceptionally well done, but were the same as the balance of the commercial plantings in the field. The entire crop made very good growth and the plots were harvested with a Marbeet Junior harvester during the second week of September.

Stand counts were taken at harvest time which indicated the following average numbers of marketable beets per 100 feet of row:

Test 1, treatment (a) — 160, (b) — 155, and (c) — 126;
Test 2, treatment (a) — 136, (b) — 126, and (c) — 111.

On the basis of the above counts of marketable beets, the actual harvest populations per acre averaged 25,787 beets for treatment (a), 24,394 beets for treatment (b) and 20,560 beets for treatment (c).

As compared with the original desired spacings at thinning of 6 inches, 8 inches and 10 inches, the beets in test 1 at harvest averaged 7.50 inches, 7.74 inches and 9.52 inches apart; in test 2, the averages were 8.82

[1]District Agriculturist, Holly Sugar Corporation.

inches, 9.52 inches and 10.81 inches apart in the row at harvest. The reduction in field populations in the close spacings was undoubtedly due to the greater competition between plants, as well as some greater mortality from hoeing operations and disease (Rhizoctonia).

Tables 1, 2 and 3 show the relative sucrose percentage, yield per acre and gross sugar per acre for test 1, test 2 and the combined results of both tests.

**Table 1.**—Relative sucrose percentage, yield per acre and gross sugar per acre for test 1.

| Treatment | Sucrose | | Yield per acre | | Gross sugar per acre | |
|---|---|---|---|---|---|---|
| | Percent | Rank | Tons | Rank | Pounds | Rank |
| 6-inch spacing | 13.05 | 3 | 42.576 | 1 | 11,116 | 3 |
| 8-inch spacing | 13.86 | 1 | 42.491 | 2 | 11,777 | 1 |
| 10-inch spacing | 13.34 | 2 | 42.363 | 3 | 11,294 | 2 |
| General Mean | 13.42 | | 42.477 | | 11,396 | |
| F Value | 3.6942 | | 26.3095* | | 2.3842* | |
| 5% point | 3.34 | | 19.45 | | 3.34 | |
| 1% point | 5.45 | | 99.46 | | 5.45 | |
| S. E. Mean | .2143 | | .5516 | | 221.3514 | |
| Difference required for significance | .62 | | 1.598 | | 641 | |

8-inch spacing is significantly above 6-inch spacing in percentage sucrose.

*No significant differences.

**Table 2.**—Relative sucrose percentage, yield per acre and gross sugar per acre for test 2.

| Treatment | Sucrose | | Yield per acre | | Gross sugar per acre | |
|---|---|---|---|---|---|---|
| | Percent | Rank | Tons | Rank | Pounds | Rank |
| 6-inch spacing | 13.30 | 1 | 43.991 | 3 | 11,702 | 2 |
| 8-inch spacing | 12.37 | 3 | 44.658 | 2 | 11,043 | 3 |
| 10-inch spacing | 12.89 | 2 | 46.385 | 1 | 11,959 | 1 |
| General Mean | 12.85 | | 45.011 | | 11,568 | |
| F Value | 2.9425* | | 9.2153 | | 3.2692* | |
| 5% point | 3.34 | | 3.34 | | 3.34 | |
| 1% point | 5.45 | | 5.45 | | 5.45 | |
| S. E. Mean | .2706 | | .4070 | | 261.3413 | |
| Difference required for significance | .78 | | 1.179 | | 757 | |

10-inch spacing is significantly above 6-inch and 8-inch spacing on tons per acre.

*No significant difference.

**Table 3.**—Relative sucrose percentage, yield per acre and gross sugar per acre for tests 1 and 2 combined.

| Treatment | Sucrose | | Yield per acre | | Gross sugar per acre | |
|---|---|---|---|---|---|---|
| | Percent | Rank | Tons | Rank | Pounds | Rank |
| 6-inch spacing | 13.17 | 1 | 43.284 | 3 | 11,409 | 3 |
| 8-inch spacing | 13.12 | 2 | 43.575 | 2 | 11,410 | 2 |
| 10-inch spacing | 13.11 | 3 | 44.374 | 1 | 11,626 | 1 |
| General Mean | 13.13 | | 43.744 | | 11,482 | |
| F Value | 31.1144* | | 2.4705* | | 2.1486* | |
| 5% point | 19.45 | | 3.15 | | 19.45 | |
| 1% point | 99.46 | | 4.98 | | 99.46 | |
| S. E. Mean | .1881 | | .3591 | | 183.4047 | |
| Difference required for significance | .53 | | 1.020 | | 521 | |

*No significant difference.

These results show that yields per acre were uniformly very high and the sugar content was uniform, but low. The plots were located in a 400-acre field which produced an average of 38.06 tons per acre with 13.55 percent sucrose content, so it is apparent that the tests were typical of the entire field.

Since there was little, if any, significant difference in the yields or gross sugar per acre between the highest and lowest field populations, we would conclude that, on fields of high fertility level, we would not expect an increase in production with beets spaced closer than 10 inches in rows 30 inches apart.

# Physiology of Growth and Mineral Intake Of Sugar Beets

M. M. Afanasiev, H. E. Morris, E. E. Frahm[1]

## Progress Report

Nutritional requirements of sugar beets pertaining to their optimal development under given environmental conditions were studied in 1947. During this year the following factors relating to the growth of sugar beets were investigated: Percentage of sugar in sugar beet roots, mineral composition of tops and roots (N, P, K, Ca and Na), top-to-root ratios of beets and the yield of sugar beets. Sugar beets were planted in plots treated with the following fertilizers: P, NP, M (manure), MK, MP, MN, MPK, MNK, MNP, and MNPK. All soil treatments and checks were used in three randomized replications. Chemical analyses and other growth determinations were made several times during the growing season beginning with the middle of July.

Although the variation in content of sugar, minerals, in top-to-root ratios and yield of beets planted in plots which received different treatments did not vary greatly, still the following trends could be detected:

1. Sugar beets grown in highly fertilized plots, on an average, had lower percentage of sugar than beets grown in check plots and those receiving partial fertilization.

2. Lower percentages of roots as compared to tops, on an average basis, occurred in beets grown in highly fertilized plots, where fertilization practically always included nitrogen, and the highest percentages of roots occurred in the checks and in those plots which were fertilized with only a single or a combination of two elements, practically always excluding nitrogen.

[1]Agricultural Experiment Station, Montana State College, Bozeman, Montana.

# Application of Liquid Fertilizers at Time of Planting

HARVEY P. H. JOHNSON[1]

STARTER SOLUTIONS are now being considered for some vegetable crops. It seems logical that plant life should benefit from special nutritional practices in the early stages of growth much as animal life does. It was with this in mind that this test of early, small applications of liquid-fertilizer was made. The purpose was to determine whether small dosages of fertilizers applied around the seed might not give the plant greater vigor and strength in its early stages of growth thereby enabling the seedling to withstand disease and weather hazards during this critical period of growth. It was felt that the amounts added were not great enough to have much influence on final yield other than the carry-over effect resulting from faster and earlier development of the seedling. The test was made in cooperation with the Agricultural Engineering Department of Colorado A & M College at Fort Collins.

The chemicals included Fertidine, Calgon, Fume Phosphate (ground treble superphosphate), ammonium sulphate, ammonium nitrate and Uramon. The chemicals were used at different rates varying from ½ pound per acre to 5 pounds per acre. Chemicals were also used in combination. Fertidine,[2] an organic iodine compound, is prepared in the form of a black powder which is readily soluble in cold water. The formula of the unit cell is $C_{36}H_{60}O_{30}I_3$ or about 20 percent iodine by weight. Preliminary observations on its use have been made by Dr. Butler[3] and others with findings showing some increase in yield, particularly with root crops such as radishes, beets and carrots, when small applications of 1 pound per acre were made. Calgon[4] is a trade name for sodium hexametaphosphate, a high $P_2O_5$ containing phosphate salt commonly used as a water softener. Uramon[5] is a nitrogen carrying fertilizer containing 42 percent nitrogen. The remaining fertilizers need no further explanation as they are common commercial fertilizers.

Application of these fertilizers was made either in solution or suspension in water. When held in suspension a detergent was used. Water cans were fastened on top of a John Deere No. 55 planter with rubber tubing leading from the water can to a quarter-inch tube inserted in the fertilizer opening of the drill furrowing-out mechanism. The water solution was placed around the seed in the seed furrow then covered by the press wheel. Water application was made at the rate of 130 gallons per acre.

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[1]Statistician-Agronomist, The Beet Sugar Development Foundation, Fort Collins, Colorado.
[2]Obtained from the Clairmint Chemical Company, Inc., 7 Lackawanna Avenue, Newark 2, N. J.
[3]Director of Research, Cooperative Grange League Federation, Ithaca, N. Y.
[4]Obtained from The Denver Fire Clay Company, Denver, Colorado.
[5]Obtained from DuPont Chemical Company, Wilmington, Delaware.

One-hundred-foot single-row plots were used with each plot replicated six times in a randomized-block design experiment. The entire row was harvested for yield with two sugar samples taken from each plot.

Early growth development was observed. When the beets were about 4 inches high two separate growth observations were recorded, one by Professor Ray Barmington of Colorado A & M College, and the other by the writer. Growth observations were recorded on the basis of giving a value of 6 to the no treatment check then assigning correspondingly higher values up to 10 for those rows in the same replication which appeared superior in growth development to the check and values down to 1 for those treatments inferior to the check. Table 1 gives the results for each treatment when values have been combined for the six replications. Each observer's results are noted together with a combined total. A correlation was made on the paired observations for each treatment. A high positive correlation of .81885 was obtained.

**Table 1.—Visual results of early growth development of sugar beets due to the application of small quantities of fertilizer at time of planting.**

| | Treatment | Observer 1 | Observer 2 | Total |
|---|---|---|---|---|
| 1. | Check (No treatment) | 36 | 36 | 72 |
| 2. | ½ pound Fertidine | 38 | 36 | 74 |
| 3. | 5 pounds Fume phosphate | 38 | 38 | 76 |
| 4. | 2½ pounds Uramon | 35 | 38 | 73 |
| 5. | 1 pound Calgon | 40 | 41 | 81 |
| 6. | 1 pound Fertidine | 39 | 37 | 76 |
| 7. | 1 pound Fume phosphate | 42 | 40 | 82 |
| 8. | 2½ pounds Uramon + 2½ pounds Fertidine | 37 | 39 | 76 |
| 9. | 2½ pounds Calgon | 37 | 37 | 74 |
| 10. | 2½ pounds Fertidine | 36 | 33 | 69 |
| 11. | 1 pound Fume phosphate + 2½ pounds Fertidine | 38 | 37 | 76 |
| 12. | 2½ pounds Ammonium sulphate | 37 | 36 | 73 |
| 13. | 5 pounds Calgon | 37 | 39 | 76 |
| 14. | 5 pounds Fertidine | 34 | 37 | 71 |
| 15. | 2½ pounds Ammonium nitrate | 38 | 39 | 77 |
| 16. | 2½ pounds Ammonium sulphate + 2½ pounds Fertidine | 40 | 40 | 80 |
| 17. | 1 pound Calgon + 2½ pounds Fertidine | 37 | 36 | 73 |
| 18. | 2½ pounds Uramon + 2½ pounds Calgon | 38 | 39 | 77 |
| 19. | 2½ pounds Ammonium nitrate + 2½ pounds Fertidine | 37 | 38 | 75 |
| 20. | 2½ pounds Uramon + 2½ pounds Calgon + 2½ pounds Fertidine | 23 | 29 | 62 |

Growth observations were recorded on the basis of giving a value of 6 to the no treatment check then assigning correspondingly higher values up to 10 for those rows in the same replication which appeared superior in growth development to the check and values down to 1 for those treatments inferior to the check.

Table 1 shows that there were some visual differences in early growth development with the small dosages of $P_2O_5$ (treatments 5 and 7) showing up most favorably. Actually the differences were greater than might be suggested in small numerical differences. The combination of too many fertilizers (treatment 20) showed a definite retardation in growth. One-half pound and 1 pound dosages of Fertidine were superior to the heavier

rates. The nitrogen additives were better than the check but did not have the responses found with the phosphates. It is felt that more information is necessary on the combinations, particularly on rates of each.

Later in the growing season, these growth differences lessened until in late July when no contrasts could be observed. Table 2 shows the harvest data. As might be expected in this field of high fertility, no significant treatment differences were apparent. The fourth column "Average weight per beet" does show some significant differences, however, this should be interpreted with extreme caution as it is obvious that most all differences are due to a compounding effect from slightly smaller stands together with equal or slightly higher weights per plot.

**Table 2.—Yields of sugar beets secured from applications of small quantities of fertilizer at time of planting.**

| Treatment[1] | Average total weight of roots per plot[2] | Average percent sucrose | Average number of beets per plot[2] | Average weight per beet | Average total sugar per plot (lbs.)[3] |
|---|---|---|---|---|---|
| Check | 62 | 13.18 | 75 | .826 | 8.1 |
| ½ pound Fertidine | 58 | 13.48 | 75 | .785 | 7.8 |
| 1 pound Fertidine | 53 | 13.62 | 73 | .719 | 7.2 |
| 2½ pounds Fertidine | 52 | 13.57 | 68 | .754 | 7.0 |
| 5 pounds Fertidine | 54 | 13.25 | 66 | .817 | 7.2 |
| 1 pound Calgon | 56 | 13.05 | 72 | .780 | 7.3 |
| 2½ pounds Calgon | 59 | 12.95 | 64 | .917 | 7.6 |
| 5 pounds Calgon | 63 | 12.70 | 64 | .987 | 8.0 |
| 1 pound Fume phosphate | 57 | 13.40 | 76 | .757 | 7.6 |
| 5 pounds Fume phosphate | 60 | 13.33 | 75 | .792 | 7.9 |
| 2½ pounds Uramon | 57 | 13.07 | 74 | .777 | 7.5 |
| 2½ pounds Ammonium sulphate | 56 | 13.12 | 71 | .797 | 7.4 |
| 2½ pounds Ammonium nitrate | 56 | 13.27 | 69 | .817 | 7.5 |
| 2½ pounds Fertidine + 2½ pounds Uramon | 59 | 13.20 | 71 | .815 | 7.7 |
| 2½ pounds Fertidine + 2½ pounds Ammonium sulphate | 60 | 13.35 | 69 | .881 | 8.0 |
| 2½ pounds Fertidine + 2½ pounds Ammonium nitrate | 61 | 12.77 | 75 | .824 | 7.9 |
| 2½ pounds Fertidine + 1 pound Fume phosphate | 58 | 13.38 | 76 | .765 | 7.8 |
| 2½ pounds Fertidine + 1 pound Calgon | 52 | 12.90 | 68 | .770 | 6.8 |
| 2½ pounds Uramon + 2½ pounds Calgon | 60 | 12.93 | 72 | .848 | 7.8 |
| 2½ pounds Uramon + 2½ pounds Calgon + 2½ pounds Fertidine | 55 | 12.80 | 69 | .798 | 7.1 |
| L.S.D. 5 percent point | --[3] | ----[3] | --[3] | .069 | --[3] |
| L.S.D. 1 percent point | --[3] | ----[3] | --[3] | .091 | --[3] |

[1]Each treatment, including the check, was applied with water at the rate of 130 gallons per acre.

[2]Each plot 100 feet in length. Entire plot harvested.

[3]No significant difference.

## Conclusions

It is apparent that this test is only exploratory and that further work is necessary to substantiate proper trends and adequate dosages. It is interesting to note, however, that early plant stimulation can be obtained by small and inexpensive applications of fertilizer at the time of planting. The phosphates showed greater response than the nitrogens. There is a danger of making too heavy applications thereby obtaining toxic rather than beneficial effects.

# Effect of Fertilizers on Diseases and Yield of Sugar Beets Planted in Depleted Soil[1]

M. M. Afanasiev

The investigation was planned to study the effect on seedling disease and yield of sugar beets of different fertilizer treatments when applied to depleted soil. Data were also secured on stands and top-to-root ratios of sugar beets in different plots.

These experiments were conducted at the Huntley Branch Station, Huntley, Montana, on land which had been alternately cropped for a number of years with barley and sugar beets, and was so depleted of its fertility that in 1940, only 6.06 tons of beets per acre were produced.

The fertilizers used in this study were nitrogenous fertilizers ("N"-sodium nitrate and ammonium sulphate), phosphate ("P" treble superphosphate) and manure ("M"), applied in the eight following combinations: PNM; $\frac{PNM}{2}$ (in this treatment half of the nitrogen was applied at the time of planting and the other half as a side dressing immediately after thinning); NM; PM; PN; M; N; P and a check. Nitrogen was applied as a mixture of equal parts of sodium nitrate and ammonium sulphate at the rate of 200 pounds per acre containing 36.5 pounds of nitrogen (N). The phosphorus was applied as treble superphosphate at the rate of 175 pounds per acre containing 80.5 pounds of $P_2O_5$. Manure was applied on the basis of 16 tons per acre. Manure and treble superphosphate were always applied in the fall before plowing.

Nitrogen was applied in an ammoniacal and nitrate form because conditions in the early spring are not favorable for rapid nitrification of ammonia. Sugar beets in their early stages of development require a considerable amount of nitrogen; therefore, it is necessary to supply them with nitrogen, such as a nitrate which is immediately available. Later when conditions become favorable for nitrification, beets can use nitrogen supplied in the form of ammonium sulphate.

Soil treatments were used in 3 randomized replications, so that, altogether, there were 27 individual plots, each consisting of 8 rows of beets 125 feet long.

All plots were treated as outlined during 1941 to 1944, inclusive. By the end of 1944 the effect of each treatment was well stabilized as far as yield, stand, seedling diseases, and top-to-root ratio of beets was con-

[1]Contribution from Montana State College, Botany and Bacteriology Department, Agricultural Experiment Station. Paper No. 201, Journal Series.

cerned. For the 1945 crop, the whole field was uniformly treated with complete fertilization (treatments PNM or $\frac{PNM}{2}$, respectively) to study its effect when superimposed over the previous treatments on sugar beets.

The land was generally plowed in the fall, double disced, harrowed and leveled in the spring and planted with U.S. 22 segmented seed.

Samples of 100 or more seedlings, in the 4- to 6-leaf stage, were taken from each plot and carefully examined for disease. During the summer, counts of the stand of beets in the four central rows of each plot were made. Only portions of the four central rows of each plot were harvested. Yield and top-to-root ratios were recorded from these samples for all plots and treatments.

## Results and Discussion

The results of these studies are presented in tables 1, 2, 3, and 4.

### Yield of Beets

The smallest yield of beets during the first 4 years occurred in the check plots (4.39 tons per acre) and the highest in treatment $\frac{PNM}{2}$ (16.27 tons per acre) where complete fertilization was used with divided application of nitrogen (table 1). This table also shows the proportional increase in yield of sugar beets grown on fertilized plots as compared to the check. The lowest increase in yield occurred in plots fertilized with nitrogen (2.64 tons per acre) and the greatest on plots fertilized with complete fertilization with divided application of nitrogen (11.88 tons per acre). The increase in yield due to other fertilizers occupies positions between these two extremes.

There was a considerable response of beets to the fertilizers in the years 1941-44. Apparently this soil was more depleted in available phosphorus than nitrogen, at least phosphorus fertilization alone gave better response than nitrogen. The best yield was obtained by applying complete fertilization with a divided application of nitrogen. The nitrogen apparently was utilized in this way better than when all of it was applied early in the spring.

All plots of this experiment were uniformly fertilized with complete fertilization for the crop of 1945, resulting in good and uniform yields. Beets grown on the previous check plots and the plots previously fertilized with phosphorus or nitrogen alone showed the greatest increase in yield (9.80, 4.36 and 6.60 tons of beets per acre, respectively). Yield of beets grown on plots previously fertilized with M, PN, and PM, showed only a moderate increase (2.31, 3.77 and 2.11 tons of beets per acre, respectively). Beets grown on the plots previously fertilized with the remaining treatments either showed only a slight increase or a slight decrease in the yield. This decrease probably was due to seasonal variations in the yield.

The results for all these years show that a good yield of sugar beets can be obtained even in poor, depleted soil providing adequate fertilization is applied to the soil. The sugar beet crop responds very quickly to increased fertility of soil.

### Stand of Beets

The stand of beets as reported in table 2 was quite good and uniform. The lowest stand of beets during the first 4 years occurred in the check plots (88.0 percent of theoretical stand 26136) and the highest in the plots treated with complete fertilization with divided application of nitrogen (101.7 percent of theoretical stand). The stand of beets in the plots treated with the remaining fertilizers, with the exception of those treated with nitrogen alone (91.9 percent of theoretical stand), was either very close to 100.0 percent or above it.

The stand of beets planted on these plots in 1945 was, in general, very good and with the exception of that of the previous check plots and those treated with phosphorus and manure (91.5 and 91.4 percent of theoretical stand, respectively) was close to 100.0 percent or above it.

### Seedling Diseases of Beets

The smallest amount of healthy beet seedlings during the first 4 years occurred in the check plots (27.8 percent) and the greatest amount occurred in the plots fertilized with a complete fertilizer with a divided application of nitrogen (75.8 percent) (table 3). Beets grown in the plots fertilized with nitrogen alone also had a low percentage of healthy seedlings (44.7 percent).

Beets grown in the remaining plots had a rather high percentage of healthy seedlings which closely approached that of treatment $\frac{PNM}{2}$.

These results emphasize the value of a complete fertilizer for the control of seedling diseases of sugar beets.

The amount of healthy seedlings in the crop of 1945, when all plots were uniformly fertilized with a complete fertilizer, was rather high. An exception was noted in those previously treated with nitrogen alone where the percentage of healthy seedlings of 1945 showed the lowest increase (5.7 percent) as compared with those for previous years. The greatest increase of healthy seedlings for 1945 occurred in the former check plots (35.4 percent). The increase of healthy beet seedlings in the plots formerly treated with the remaining fertilizers varied between 9.2 and 17.2 percent over those which occurred during the years 1941-1944.

These results show that the amount of seedling diseases of sugar beets could be materially decreased by increasing the fertility of the soil. Also it is apparent that the nitrogen present in the soil in an unbalanced condition may predispose young beets to seedling diseases. This was evident even in the crop planted in 1945 when all plots were uniformly fertilized with complete fertilizers.

### Top-to-Root Ratio

Beets, during the first 4 years, had the smallest percentage of tops and the greatest percentage of roots in the plots treated with the following amendments: P, PN, PM, and PNM (table 4). The greatest percentage of tops and the smallest percentage of roots in the same years occurred in the beets in the check plots and the plots fertilized with nitrogen. The top and root proportions of beets grown with the remaining treatments occupy an intermediate position.

These top-to-root proportions show that apparently there was a slight excess of nitrogen or extreme deficiency of phosphorus or both, in soils of check plots and of those fertilized with nitrogen. These plots had an unproportionally large development of the tops in comparison with the roots.

The top-to-root proportions of beets grown in the plots fertilized with P, PN, and PM approach the ideal ratio desired at the harvest time.

Top-to-root ratios of the beets grown in all fertilized plots in 1945 showed that in general they varied less than for the years of 1941-1944. Beets grown in the plots previously fertilized with P and PN showed proportionally the highest development of roots, and those fertilized with NM and $\frac{PNM}{2}$ the highest development of tops. These results indicate that there was a residual effect of the previous fertilizers on the 1945 crop of beets.

Top-to-root ratios of sugar beets in combination with the yield data offer a good criterion for judging the total and proportional balance of nutrients available to sugar beets in any particular soil under given conditions.

It appears that the most favorable ratio of tops to roots of beets at the time of harvest is equal to 35 to 40 percent for tops and 60 to 65 percent for roots. Much variation from these percentages may be interpreted in relation to mineral nutrition or environmental conditions during the growth of the beets.

In general, an excess of nitrogen and deficiency of phosphorus usually supports a proportionally greater development of tops, while an excess of phosphorus and deficiency of nitrogen results in proportionally greater development of roots.

The actual size of the tops and the roots is limited by the amounts of available nutrients in the soil, and especially by those which are in a minimum quantity.

### Summary

1. Sugar beets showed a proportional effect of the different nutrients on yield, stand, seedling diseases and top-to-root ratios when planted in depleted soil.

2. Beets fertilized with NM, PNM and $\frac{PNM}{2}$ produced the best yields in the first 4 years, and those fertilized with nitrogen alone and the

checks, the poorest. The beets grown in the remaining plots produced intermediate yields. The yields of beets grown in all these plots fertilized in 1945 with complete fertilization were uniformly good. The greatest increase in yield was shown by the previous check plots and those fertilized by phosphorus or nitrogen alone. This shows an ability of beets to respond quickly to an increase in fertility of soil.

3. Stands of beets were quite good in all years of study. They were all above 90 percent of the theoretical stand except the check plots for the first 4 years of study.

4. The percentage of healthy beet seedlings in the first 4 years of study was the highest in plots fertilized with $\frac{PNM}{2}$ and the lowest in the check plots and those fertilized with nitrogen alone. The percentages of healthy seedlings in the remaining plots were fairly good and occupy intermediate positions between the above mentioned extremes. The percentage of healthy seedlings in the crop of beets grown in 1947 was considerably higher for the corresponding plots of previous treatments. The greatest increase in the percentage of healthy seedlings as a result of complete fertilization was obtained in previous check plots and the lowest in those where nitrogen alone was previously applied. The increase in percentages of healthy seedlings in the remaining plots of the previous treatments occupy intermediate positions.

5. Beets grown in the plots treated with P, PN, PM and PNM during the first 4 years had the smallest percentages of tops and the largest percentages of roots. Beets grown in checks and in those fertilized with nitrogen had the greatest percentages of tops and lowest percentages of roots. Beets grown in the plots of the remaining treatments occupy an intermediate position. Top-to-root ratios of beets grown in all plots in 1945, when complete fertilization was applied, were more uniform for all previous treatments and checks than in 1942-44.

6. In general, these results show that the fertility of the soil has a great effect on the yield, stand, seedling disease and top-to-root ratios of sugar beets, which is in accordance with results obtained in previous years.

**Table 1.—Effect of fertilizers on yield of sugar beets planted in depleted soil, 1941-1944, 1945.**

| Fertilizers applied | Yield of sugar beets per acre in tons | | | | | |
|---|---|---|---|---|---|---|
| | 1941 (tons) | 1942 (tons) | 1943 (tons) | 1944 (tons) | 1941-1944 Average (tons) | 1945 (tons) |
| Check | 3.02 | 3.50 | 6.70 | 4.33 | 4.39 | 14.19 |
| P | 8.66 | 8.20 | 10.31 | 11.00 | 9.54 | 13.90 |
| N | 6.86 | 6.77 | 7.56 | 6.94 | 7.03 | 13.63 |
| M | 12.11 | 11.21 | 13.15 | 14.12 | 12.65 | 14.96 |
| PN | 9.87 | 8.79 | 12.26 | 12.31 | 10.81 | 14.58 |
| PM | 12.16 | 13.19 | 14.14 | 14.00 | 13.37 | 15.48 |
| NM | 13.46 | 15.67 | 15.11 | 14.69 | 14.73 | 14.86 |
| PNM | 14.45 | 14.98 | 15.22 | 14.99 | 14.91 | 14.40 |
| $\frac{PNM}{2}$ | 15.44 | 18.04 | 15.76 | 15.84 | 16.27 | 15.04 |

**Table 2.—Effect of fertilizers on stand of sugar beets planted in depleted soil, 1941-1944, 1945.**

| Fertilizers applied | Percent of theoretical stand (26136) of beets | | | | | |
|---|---|---|---|---|---|---|
| | 1941 (percent) | 1942 (percent) | 1943 (percent) | 1944 (percent) | 1941-1944 Average (percent) | 1945 (percent) |
| Check | 71.9 | 89.1 | 103.6 | 87.4 | 88.0 | 91.5 |
| P | 90.7 | 114.7 | 108.4 | 89.4 | 100.8 | 95.8 |
| N | 81.9 | 97.6 | 103.2 | 85.0 | 91.9 | 102.9 |
| M | 82.4 | 111.2 | 103.0 | 81.9 | 94.6 | 96.1 |
| PN | 84.3 | 113.5 | 111.0 | 90.0 | 99.7 | 106.5 |
| PM | 84.7 | 116.2 | 106.7 | 81.7 | 97.3 | 91.4 |
| NM | 87.1 | 119.1 | 105.5 | 89.7 | 100.4 | 108.1 |
| PNM | 92.6 | 115.9 | 107.7 | 84.1 | 100.1 | 96.7 |
| $\frac{PNM}{2}$ | 87.5 | 121.5 | 111.1 | 86.7 | 101.7 | 97.5 |

**Table 3.—Effect of fertilizers on seedling disease of sugar beets planted in depleted soil, 1941-1944, 1945.**

| Fertilizers applied | Percent of healthy seedlings | | | | | |
|---|---|---|---|---|---|---|
| | 1941 (percent) | 1942 (percent) | 1943 (percent) | 1944 (percent) | 1941-1944 Average (percent) | 1945 (percent) |
| Check | 0.6 | 14.0 | 47.5 | 48.9 | 27.8 | 63.2 |
| P | 5.4 | 64.0 | 81.3 | 86.5 | 59.3 | 72.1 |
| N | 8.1 | 40.7 | 58.1 | 72.0 | 44.7 | 50.4 |
| M | 16.5 | 81.8 | 90.2 | 86.9 | 68.9 | 86.1 |
| PN | 19.0 | 84.5 | 73.1 | 89.3 | 66.5 | 78.9 |
| PM | 21.4 | 88.1 | 82.3 | 90.2 | 70.5 | 85.9 |
| NM | 16.1 | 86.3 | 84.7 | 92.6 | 69.9 | 79.1 |
| PNM | 32.2 | 83.5 | 85.5 | 93.5 | 73.7 | 83.0 |
| $\frac{PNM}{2}$ | 31.0 | 90.4 | 90.1 | 91.5 | 75.8 | 92.6 |

**Table 4.—Effect of fertilizers on top-to-root ratios of sugar beets planted in depleted soil, 1942-1944, 1945.**

| Fertilizers applied | Top-to-root ratios of sugar beets. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1942 | | 1943 | | 1944 | | 1942-1944 Average | | 1945 | |
| | Tops % | Roots % | Tops % | Roots % | Tops % | Roots % | Tops % | Roots % | Tops % | Roots % |
| Check | 66.7 | 33.3 | 49.0 | 51.0 | 50.5 | 49.5 | 55.4 | 44.6 | 48.8 | 51.2 |
| P | 43.9 | 56.1 | 37.1 | 62.9 | 35.8 | 64.2 | 38.9 | 61.1 | 45.3 | 54.7 |
| N | 56.0 | 44.0 | 56.3 | 43.7 | 53.5 | 46.5 | 55.3 | 44.7 | 48.9 | 51.1 |
| M | 42.3 | 57.7 | 47.0 | 53.0 | 48.9 | 51.1 | 46.1 | 53.9 | 50.7 | 49.3 |
| PN | 48.1 | 51.9 | 43.5 | 56.5 | 38.2 | 61.8 | 43.3 | 56.7 | 46.1 | 53.9 |
| PM | 39.7 | 60.3 | 42.2 | 57.8 | 44.3 | 55.7 | 42.1 | 57.9 | 50.9 | 49.1 |
| NM | 40.1 | 59.9 | 52.7 | 47.3 | 50.3 | 49.7 | 47.7 | 52.3 | 54.8 | 45.2 |
| PNM | 40.8 | 59.2 | 46.7 | 53.3 | 46.4 | 53.6 | 44.6 | 55.4 | 51.3 | 48.7 |
| $\frac{PNM}{2}$ | 43.6 | 56.4 | 47.8 | 52.2 | 48.2 | 51.8 | 46.5 | 53.5 | 54.9 | 45.1 |

# Results on Different Seeding Rates of Sugar Beets as Affecting Yield and Hand Labor Requirements

R. T. Nelson and R. R. Wood[1]

The use of segmented or otherwise processed beet seed has been almost universally adopted by the beet sugar industry of North America. That labor was saved by its adoption appeared obvious. The amount of labor saved or the relative yield resulting from plantings of segmented seed as compared with whole seed was not so certain. In the first place, factors affecting the results of such comparisons are numerous. The seeding rates used, methods of thinning, type labor employed, soil and weather conditions are all important factors influencing the final results. To make the direct comparison, however, is not as important as determining the point at which one reduces the hand labor requirements to a minimum without a sacrifice in yield or net return.

This paper deals with two studies—one made on the Experiment Station at Longmont, Colorado, and the other on farmers' fields at Billings, Montana, during the year 1947.

## Materials and Methods

The seed used in the experiment conducted at Longmont consisted of a 1:1 mixture by weight of two commercial G.W. varieties. The number of seedballs per pound before segmenting was 35,600 with an average germination of 79 percent. After segmenting, there were 48,000 seedballs per pound with a total germination of 78.5 percent, of which 58.6 percent were singles. The field selected was of medium fertility and the planting was made April 30, under adverse germinating conditions. A John Deere No. 66 beet drill was used for planting the segmented seed and a hand planter for planting the whole seed. Flat bed planting with 20-inch rows was used. Six rows 300 feet long constituted a plot. Laborers were employed by the hour and were not professional beet workers. Two center rows the length of the plot were harvested for yield September 30. One-half this quantity of beets was used for sugar analysis.

The experimental design used at Longmont was that of a complete randomized block with five treatments and five replications. The five treatments were respectively:

a. 1 pound segmented seed per acre, no thinning.

b. 2 pounds segmented seed per acre, long-handled hoe thinned at 4- to 6-leaf stage.

[1]Agronomist, The Great Western Sugar Company Experiment Station, Longmont, Colorado, and Agronomist, The Great Western Sugar Company, Billings, Montana, respectively.

c. 4 pounds segmented seed per acre, long-handled hoe thinned at 4- to 6-leaf stage.

d. 4 pounds segmented seed per acre, hand-blocked and thinned at 10- to 12-leaf stage.

e. 20 pounds whole seed per acre, hand-blocked and thinned at 10- to 12-leaf stage.

In addition to the test just described, observations were made of low seeding rate trials conducted on selected farms near Billings, Montana. The summarized data as presented later in tabular form are self-explanatory. Restrictions concerning the trials were made only in the attempt to select fields relatively free of weeds and of reasonably good fertility.

## Experimental Results

The data secured on the test conducted at Longmont are given in tables 1 and 2.

**Table 1.—Pre-thinning and after-thinning stand counts for different seeding rates and thinning methods.**

| Treatment | Rate of seeding | Method of thinning | Plants per 100′ of Row | |
|---|---|---|---|---|
| | | | Before thinning | After thinning |
| a. | 1 pound per acre | None | 50 | 50 |
| b. | 2 pounds per acre | Long-handled hoe | 100 | 72 |
| c. | 4 pounds per acre | Long-handled hoe | 183 | 92 |
| d. | 4 pounds per acre | Hand-blocked and thinned** | 183 | 79 |
| e. | 20 pounds per acre* | Hand-blocked and thinned** | 990 | 95 |

*Whole seed, others segmented seed.
**Delayed thinning, others thinned early.

**Table 2.—Yield results and man hours used for thinning and hoeing.**

| Treatment | Roots per acre (tons) | Sugar content (percent) | Sugar per acre (pounds) | Hand labor hours per acre | | |
|---|---|---|---|---|---|---|
| | | | | Thinning | Hoeing | Total |
| a. | 8.25 | 10.56 | 1742 | --- | 13.0 | 13.0 |
| b | 10.47 | 11.00 | 2303 | 7.6 | 9.3 | 16.9 |
| c. | 11.24 | 12.46 | 2801 | 8.2 | 11.3 | 19.5 |
| d. | 10.76 | 12.38 | 2664 | 36.7 | 5.1 | 41.8 |
| e. | 10.48 | 12.72 | 2666 | 50.7 | 5.7 | 56.4 |
| LSD 5 percent point | 1.27 | .54 | 317 | --- | --- | --- |
| LSD 1 percent point | 1.73 | .74 | 438 | --- | --- | --- |

The pre-thinning counts represent from 18 to 20 percent emergence of the total potential germination in the case of the segmented seed and 25 percent of the total potential for the whole seed.

The harvest results and hand labor requirements for the various treatments are given in table 2.

The relatively low yields as presented in table 2 may be attributed, in part, to late seeding, one severe hail June 27, and an early harvest. Even though the yields in tons per acre are not significantly different at the 5 percent point between treatments c and e, the trend in yield suggests that competition resulting from heavy rates of seeding and late thinning

adversely affected the yield. The labor required was increased by an abundant growth of weeds. This was apparent whether the thinning was done early or late.

The information on low seeding rates as obtained by cooperation with different growers in Montana is given in table 3.

**Table 3.—Results of semi-commercial trials with low seeding rates. Billings, Montana, 1947.**

| Grower | Acres planted (number) | Seed per acre (pounds) | Hills per 100 feet (number) | Spring labor cost per acre | Yield per acre (tons) | Yield on whole contract (tons) |
|---|---|---|---|---|---|---|
| Al DeMeyer | 4.4 | 1 | 65 | $12.50 | 19.47 | 19.93 |
| Alec and Herman Popp | 12.0 | 1 | 45 | Own family | 15.09 | 14.28 |
| Henry Rush | 3.4 | 2 | 65 | $22.00 | 17.68 | 14.10 |
| Loren Hill | .9 | 1 | 94 | Own family | No harvest data | |

In the results of table 3 it is significant to note that good crops were produced with as low a seeding rate as 1 pound of seed per acre on the farms observed. It is the opinion of the writers that many growers in the Yellowstone Valley have the requirements which tend to favor such a minimum rate. Their main advantage is in having irrigation water available for irrigating the beets up if soil moisture is low. The results of the test at Longmont (tables 1 and 2) show a favorable yield for pre-thinning stands of as low as 200 plants per 100 feet of row. Under conditions of uniform planting and uniform emergence as obtained at Longmont, this stand was ample. Light stands of beets can be worked easily by hand labor, using long-handled hoes with a marked saving in time, effort, and cost. With a number of growers the low seeding rates have been more acceptable than the method employing heavier rates of seeding and cross-blocking. Those afraid of having a crop failure because of low seeding might look toward making a double planting in the same field and cultivating out rows not desired at the time of the first cultivation. It appears to the writers that this might require special equipment that would plant both rates in one operation with special attention given to row and wheel spacings to avoid planting in wheel marks. The experience with a double planting this year indicated the numerous tractor wheel marks made by two separate planting operations disturbed the seedbed. The seriousness of this did not appear great but it is mentioned as it might become an important factor depending on the condition of the soil.

## Summary and Conclusions

1. A seeding rate of 1 pound per acre employed in a test at Longmont, Colorado, under adverse germinating conditions lowered the yield in tonnage by one-fourth and sugar produced per acre even more.

2. A seeding rate of 2 pounds per acre gave an emergence of 100 beets per 100 feet of row. This rate of seeding compared favorably in tonnage to heavier rates of seeding but produced less sugar per acre compared to stands obtained as a result of heavier rates of seeding.

3. Yields obtained from a 4-pound seeding of segmented seed was equivalent to yields obtained from a seeding of 20 pounds per acre of whole seed and resulted in a large saving in labor.

4. The seeding rate should be governed by the anticipated percentage emergence. A seeding rate that produced 180 beets per 100 feet of row was ample in a test at Longmont where a precision planter and hoe thinning was used. Seeding rates as low as 1 pound per acre have shown considerable promise in the Billings, Montana, area.

# Fertilizer Trials in Southeastern Colorado

C. E. Cormany, E. P. Pattison, and J. T. Alexander[1]

For the past several years, the sucrose percentage of beets grown in the lower Arkansas Valley of Colorado has been unusually low.

Previous studies (1), (2), indicated that phosphoric acid was the plant-food element most deficient for sugar beet production in this area.[2] Nitrogen was found to be deficient in the lighter textured soils. Little response had been observed from applications of potassium.

This study was designed to determine the effect of different fertilizer applications on the gross yield of sugar per acre for the lower Arkansas Valley of Colorado.

Two fields located near Bristol, Colorado, were used for these tests. The soil on each field was classified as a silt loam. They had a pH of 8.1. Each test consisted of eleven different fertilizer treatments in comparison to the check. In addition, one field received 10 tons of barnyard manure per acre. Phosphate treatments consisted of 43 percent treble-superphosphate applied at planting time. Nitrogen treatments consisted of sulfate of ammonia applied as a side-dressing after thinning. The potash treatment was applied at planting time. The unmanured field had an insufficient amount of irrigation during the growing season. (This undoubtedly accounts for the low yields produced, and for the erratic response obtained from the fertilizer treatments on this field.)

The treatments were replicated three times on the unmanured field and four times on the manured field. Analysis of variance was applied to a randomized block design in the statistical analysis of the data. In order to better summarize the results, the data from both fields were combined and another analysis was made. The results for the unmanured field are shown in table 1; those for the manured in table 2; and those for the two fields combined in table 3. (Tables 1, 2, 3 appended).

## Discussion

Although the results of this test are not highly significant statistically, some definite trends are apparent. It is of interest to note that the manured field utilized more nitrogen than was formerly believed necessary for optimum yield. The highest yield in sugar per acre was obtained from the treatment having the most nitrogen present; namely, 400 pounds of 4-24-4 mixture side dressed with 300 pounds of sulfate of ammonia, a total of 77 pounds of nitrogen. The ratio of nitrogen to phosphorus is only 1:1.2. It is of interest to note that a rather narrow N/P ratio is exhibited in the

[1]Chief Agronomist, Agricultural Mechanization Superintendent, and Associate Agronomist, respectively, Holly Sugar Corporation.

[2]The numbers in parentheses refer to literature cited.

Note: The writers are indebted to Professor Robert Gardner of the Agronomy Department, Colorado A & M College for his advice in outlining the treatments used in this test.

treatments ranked in the upper five. The reverse trend is evident in the unmanured field. The treatments having the widest N/P ratios show the greatest yield in sucrose per acre. The manured field was much more active biologically and probably made more efficient use of nitrogen added in the fertilizers.

No response was observed for the treatment containing potassium on either field.

The combined analysis of the two fields shows that a response can be expected from the addition of both phosphorus and nitrogen. The combined analysis does not show any definite trend in the relationship of nitrogen to phosphorus.

## Summary

The efficiency of the commercial fertilizer was increased by the addition of manure to the soil.

A definite response from side-dressing with complete fertilizers and fertilizers containing nitrogen and phosphorus was noted.

A definite response was secured from applications of phosphate fertilizers.

The most satisfactory treatment for this local area, considering both economy and plant response, appears to be an application of 400 pounds per acre of 43 percent treble-superphosphate with a side-dressing of 300 pounds per acre of sulfate of ammonia applied after thinning.

**Table 1.**—Results of fertilizer tests on an unmanured field in the Lower Arkansas Valley of Colorado, 1947.

| Treatment | Sucrose | | Gross sugar per acre order | | | |
|---|---|---|---|---|---|---|
| | | | Yield per acre | | Gross sugar per acre | |
| | Percent | Percent of check | Tons | Percent of check | Pounds | Percent of check |
| 400 pounds 0-43-0 | 11.07 | 96 | 13.779 | 117 | 3062 | 111 |
| 600 pounds 0-43-0 | 11.47 | 99 | 13.315 | 113 | 3058 | 111 |
| 300 pounds 20.5-0-0+ 600 pounds 0-43-0 | 10.75 | 93 | 13.291 | 113 | 2898 | 105 |
| Check (no treatment) | 11.57 | 100 | 11.747 | 100 | 2749 | 100 |
| 200 pounds 0-43-0 | 10.98 | 95 | 12.113 | 103 | 2665 | 97 |
| 300 pounds 20.5-0-0+ 400 pounds 4-24-4 | 9.85 | 85 | 13.453 | 115 | 2656 | 97 |
| 300 pounds 20.5-0-0+ 200 pounds 0-43-0+ 100 pounds 0-0-50 | 10.50 | 91 | 12.266 | 104 | 2597 | 94 |
| 200 pounds 4-24-4 | 11.47 | 99 | 11.431 | 97 | 2597 | 94 |
| 300 pounds 20.5-0-0+ 200 pounds 0-43-0 | 9.97 | 86 | 12.340 | 105 | 2424 | 88 |
| 400 pounds 4-24-4 | 10.25 | 89 | 11.427 | 97 | 2321 | 84 |
| 300 pounds 20.5-0-0+ 200 pounds 4-24-4 | 9.37 | 81 | 12.030 | 102 | 2260 | 82 |
| 300 pounds 20.5-0-0+ 400 pounds 0-43-0 | 9.88 | 85 | 11.167 | 95 | 2188 | 80 |
| General mean | 10.59 | | 12.363 | | 2623 | |
| F value | 1.6823* | | * | | * | |
| 5 percent point | >2.23 | | * | | * | |
| 1 percent point | >3.12 | | * | | * | |
| S. E. mean | .5672 | | * | | * | |
| Difference required for significance | 1.66 | | * | | * | |

*No significant differences.

**Table 2.**—Results of fertilizer tests on a manured field in the Lower Arkansas Valley of Colorado, 1947.

| Treatment | Sucrose | | Gross sugar per acre order | | | |
|---|---|---|---|---|---|---|
| | | | Yield per acre | | Gross sugar per acre | |
| | Percent | Percent of check | Tons | Percent of check | Pounds | Percent of check |
| 300 pounds 20.5-0-0 + 400 pounds 4-24-4 | 13.42 | 111 | 18.718 | 137+ | 5010 | 149+ |
| 300 pounds 20.5-0-0 + 400 pounds 0-43-0 | 13.08 | 108 | 18.856 | 138+ | 4948 | 148+ |
| 300 pounds 20.5-0-0 + 600 pounds 0-43-0 | 12.95 | 107 | 18.650 | 137+ | 4828 | 144+ |
| 300 pounds 20.5-0-0 + 200 pounds 0-43-0 | 12.72 | 105 | 17.945 | 132+ | 4566 | 136+ |
| 300 pounds 20.5-0-0 + 200 pounds 4-24-4 | 12.26 | 101 | 18.258 | 134+ | 4476 | 134+ |
| 200 pounds 4-24-4 | 13.64 | 113 | 16.351 | 120+ | 4406 | 131+ |
| 300 pounds 20.5-0-0 + 200 pounds 0-43-0 + 100 pounds 0-0-50 | 12.50 | 103 | 17.540 | 129+ | 4366 | 130+ |
| 600 pounds 0-43-0 | 13.39 | 111 | 16.323 | 120+ | 4355 | 130+ |
| 400 pounds 4-24-4 | 12.90 | 107 | 16.742 | 123+ | 4315 | 129+ |
| 200 pounds 0-43-0 | 13.01 | 108 | 15.692 | 115 | 4079 | 122 |
| 400 pounds 0-43-0 | 13.01 | 108 | 15.221 | 112 | 3969 | 118 |
| Check (no treatment) | 12.10 | 100 | 13.644 | 100 | 3352 | 100 |
| General mean | 12.92 | | 16.995 | | 4389 | |
| F value | 1.2783* | | 4.6280 | | 2.8824 | |
| 5 percent point | >2.04 | | <2.27 | | <2.27 | |
| 1 percent point | >2.74 | | <3.17 | | 2.84 | |
| S. E. of a mean | .4088 | | .7544 | | 268.4334 | |
| Difference required for significance | 1.18 | | 2.179 | | 775 | |

*No significant difference.

Where treatments differ significantly from the check (no treatment) they are marked + or —, indicating whether they are above or below the check.

**Table 3.**—The combined results of fertilizer tests on manured and unmanured fields in the Lower Arkansas Valley of Colorado, 1947.

| Treatment | Sucrose | | Gross sugar per acre order | | | |
|---|---|---|---|---|---|---|
| | | | Yield per acre | | Gross sugar per acre | |
| | Percent | Percent of check | Tons | Percent of check | Pounds | Percent of check |
| 300 pounds 20.5-0-0 + 400 pounds 4-24-4 | 11.89 | 100 | 16.462 | 128+ | 4001 | 129 |
| 300 pounds 20.5-0-0 + 600 pounds 0-43-0 | 12.01 | 101 | 16.353 | 127+ | 4001 | 129 |
| 600 pounds 0-43-0 | 12.56 | 106 | 15.034 | 117+ | 3799 | 123 |
| 300 pounds 20.5-0-0 + 400 pounds 0-43-0 | 11.71 | 99 | 15.561 | 121+ | 3765 | 122 |
| 300 pounds 20.5-0-0 + 200 pounds 0-43-0 | 11.54 | 97 | 15.543 | 121+ | 3648 | 118 |
| 200 pounds 4-24-4 | 12.71 | 107 | 14.242 | 111 | 3631 | 117 |
| 300 pounds 20.5-0-0 + 200 pounds 0-43-0 + 100 pounds 0-0-50 | 11.64 | 98 | 15.280 | 119+ | 3608 | 117 |
| 400 pounds 0-43-0 | 12.18 | 103 | 14.603 | 114 | 3580 | 116 |
| 300 pounds 20.5-0-0 + 200 pounds 4-24-4 | 11.02 | 93 | 15.589 | 121+ | 3527 | 114 |
| 200 pounds 0-43-0 | 12.14 | 102 | 14.158 | 110 | 3473 | 112 |
| 400 pounds 4-24-4 | 11.76 | 99 | 14.464 | 113 | 3460 | 112 |
| Check (no treatment) | 11.87 | 100 | 12.831 | 100 | 3094 | 100 |
| General mean | 11.92 | | 15.010 | | 3632 | |
| F value | 1.7320* | | 2.2621 | | 1.2087* | |
| 5 percent point | >1.89 | | <2.10 | | >1.89 | |
| 1 percent point | >2.45 | | >2.45 | | >2.45 | |
| S. E. of a Mean | .3442 | | .6779 | | 225.7305 | |
| Difference required for significance | .97 | | 1.917 | | 638 | |

*No significant difference.

Where treatment differs significantly from the check (no treatment) they are marked + or —, indicating whether they are above or below the check.

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1934. Fertilizer studies with sugar beets in the Arkansas Valley area, Colorado, 1921-28. U.S.D.A. Cir. 319, August.

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1942. Resume of commercial fertilizer studies with sugar beets. Proc. Amer. Soc. Sugar Beet Tech. p.p. 138-146.

# A Preliminary Report on the Relative Efficiency of Some Phosphate Fertilizers on Calcareous Soil

J. L. WURSTEN[1]

KNOWLEDGE OF THE REACTIONS that take place when phosphate fertilizers are applied to soils is of great scientific and practical value in crop production. Most of the investigations have been made with acid soils. It has been shown that some of the phosphate applied to such soils may be tied up with the soil and rendered unavailable to plants. Therefore, much consideration has been given to time of application and placement of the fertilizer. Some of the conclusions reached from studying acid soils have been erroneously applied to calcareous soils.

Unpublished fertilizer investigational work by the University of Idaho has indicated that some reduction in availability may occur when phosphate fertilizers are added to calcareous soils. However, succeeding crops were able to utilize a large portion of the phosphate held in the soil. This would indicate that the so-called fixation in calcareous soils is not as significant a factor in determining time and placement of fertilizer as it is in acid soils.

Field and greenhouse tests have further shown that phosphate fertilizers, having much of their phosphate in the water-soluble fractions, were more effective than those containing a large part of their available phosphorus in the citrate-soluble form.

These facts are very important to the farmers and to the fertilizer industry in the intermountain west. The Simplot Fertilizer Company of Pocatello, Idaho, made available a fellowship at the University of Idaho during 1947 for further study of:

1.—Extent of so-called fixation and/or reversion of phosphate fertilizers in calcareous soils.

2.—The extent to which the fixed or reverted phosphate, if any, may be available for crop use.

3.—The types of phosphate fertilizers best suited for use on calcareous soils.

4.—The extent to which these facts may influence time and method of applying phosphate fertilizers to calcareous soils.

This paper is a brief preliminary progress report of the findings, which should be of value to the sugar beet industry of the intermountain areas and other agricultural areas where the soils are calcareous.

**Soil.**—The soil used in this study is described in the Blackfoot-Aberdeen Area Survey Report, 1943, as Bannock loam. It was obtained from

[1]Agronomist, Simplot Fertilizer Company, Pocatello, Idaho.

a portion of an alfalfa field which had not received phosphate fertilizer. A fertilizer trial on the field showed the soil to be very deficient in phosphorus available for plant use.

A chemical analysis of the well-mixed soil before starting the investigation gave the following:

$_pH$: 7.8
Calcium carbonate equivalent: 6.1 percent
Available $P_2O_5$: 8.3 pounds/acre.

**Procedure.**—Two methods were used to determine the available phosphorus level in the soil, i.e., biological—the growing of Romaine lettuce by the method of Jenny,[2] and chemical—the carbon-dioxide extraction method.

Romaine lettuce has been used by Jenny as an indicator plant in determining nutrient levels of soil in greenhouse-pot studies. It has been observed that the growth of Romaine lettuce was in correlation to the amount of available plant nutrients in the soil. Thus it appeared that the relative growth of Romaine lettuce would be an excellent biological method of determining the availability of phosphate if nitrogen and potash requirements were met.

Previous work at Idaho[3] has established a good correlation between plant growth and available phosphorus, as determined by the carbon-dioxide method.

Four phosphate carriers were used in this study: Single superphosphate, trebel superphosphate, fused tricalcium phosphate and c.p. precipitated tricalcium phosphate. Two rates of application were used, 50 and 100 pounds of available $P_2O_5$ per acre, based on the manufacturer's guaranteed analysis (table 1).

The four phosphate carriers, at two rates of application, were each mixed with 35 pounds of soil, brought up to field-moisture capacity, and incubated for various periods of time. Incubation refers to the number of days, following fertilizer application and preceding planting, that the soils were held at optimum moisture conditions.

The following incubation periods were used:

1.—Zero or no incubation—soil moistened, planted, and soil samples taken as soon as possible.
2.—Thirty days.
3.—Sixty days.
4.—Ninety days.

Soil samples were taken from each incubation period at the following time intervals: Immediately, 1, 4, 8, 12, 20, 30, 60, and 90 days. Available phosphorus at each time interval was determined by the carbon-dioxide extraction method. The results are shown graphically in figure 1.

[2]Jenny, H.—"Nutrient Level Determination by Greenhouse Pot Studies." Mimeograph.
[3]Ensminger, L. E., and Larson, H. W. E., 1944—"Carbonic Acid Soluble Phosphorus and Lime Content of Idaho Soils in Relation to Crop Response to Phosphate Fertilization." Soil Sci., 58, No. 4.

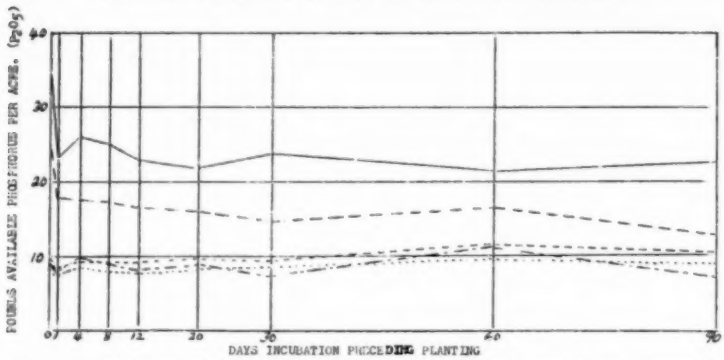


Figure 1.—Available soil phosphorus, determined by the carbon-dioxide method, as influenced by application of certain phosphate carriers and incubation with the soil.

..... Check

WATER-SOLUBLE TYPE:

———— 100 pounds available $P_2O_5$/acre. — — — 50 pounds available $P_2O_5$/acre.

CITRATE-SOLUBLE TYPE:

– – – – – 100 pounds available $P_2O_5$/acre. – – – – – 50 pounds available $P_2O_5$/acre.

At the end of each incubation period, 1,600 grams of soil from each treatment were placed in 6-inch flower pots and Romaine lettuce transplanted to each pot according to the method of Jenny. Nitrogen and potassium were added to remove any possibility of these becoming limiting plant growth factors. The lettuce plants were allowed to grow 6 weeks. They were then harvested, oven dried, and weighed. A second crop was planted without disturbing the soil in the pots. Nitrogen and potassium were added, as at the start, and the same procedure followed.

It was observed, during the progress of this work, that both the growth response of lettuce and the available phosphorus remaining in the soil, after fertilizer treatments, readily divided the fertilizers into two groups according to the proportion of water-soluble or citrate-soluble phosphorus they contained. This was substantiated later by statistical methods. Therefore, the results presented in this paper are expressed in terms of the averages obtained from the water-soluble phosphate carriers, the citrate-soluble phosphate carriers, and the check soils.

## Discussion

Data in figure 1 show that when various types of phosphate carriers were added to a calcareous soil an immediate reduction in availability took place. This reduction was practically completed within 24 hours, after which a fairly constant level of availability was maintained throughout the balance of the incubation periods.

The 100-pound applications of the water-soluble-type phosphate fertilizers maintained a level of available phosphate at 22 to 25 pounds per acre and the 50-pound applications maintained a level of 13 to 18 pounds

per acre. The citrate-soluble-type phosphate fertilizers applied at both rates gave a level of 8 to 10 pounds per acre which was not statistically different from approximately 8 pounds in the check.

Past work with alfalfa at the Aberdeen Experiment Station and unpublished data on calcareous soils from various sections of southern Idaho have shown that a level of 25 to 30 pounds of available phosphate per acre (as determined by the carbon-dioxide method) is required to obtain high crop yields.

The yield data from the greenhouse tests correlates very closely with the conclusions arrived at by the carbon-dioxide extraction method (figures 1 and 2). The higher yields of the first crops on soil which had no incubation, when compared with the first crops on soil which had 30- and 60-day incubations, indicate a drop in available phosphorus after the soil has been incubated, and a leveling off where the equilibrium of phosphorus in the soil solution has been established. The yield data on the second crop indicate that the supply of phosphorus present was being gradually depleted by crop growth.

The 100-pound applications (available $P_2O_5$) of the water-soluble-type fertilizers caused the greatest plant response. The next greatest response resulted from the 50-pound applications of the same material. Neither the 100- nor the 50-pound applications (available $P_2O_5$) of the citrate-soluble-type fertilizers showed significant increase in plant response over the check.

As shown in figure 3, Romaine lettuce plants were able to extract much more phosphorus from soil to which water-soluble-type fertilizer had been added than they could from soil to which the citrate-type fertilizer had been added. There is a gradual depletion of the water-soluble supply of phosphorus in the soil as a result of continuous cropping.

Various implications and conclusions can be derived from the study of available phosphorus in the soil with different phosphate carriers, as determined chemically (carbon-dioxide method) and from plant yield data.

High levels of available phosphorus in the soil solution of calcareous soils can be maintained by addition of water-soluble-type phosphate fertilizers. An indication of the need for phosphate fertilizer can be made by analysis for available phosphorus by the carbon-dioxide method.

The level of available phosphorus reaches equilibrium so rapidly in calcareous soils, when water-soluble-type phosphate fertilizers are applied, that the time of application of these fertilizers is less important than formerly thought. The rapidity of this reduction in availability makes it impossible even to get seeds germinated before this action has been largely completed and the phosphorus equilibrium established in the soil.

It is, therefore, indicated that water-soluble-type phosphate fertilizers can be applied in the fall or any other season on calcareous soils without any further loss of efficiency than would occur if applied immediately preceding the planting of crops. However, there probably will be an advantage to side-dressing water-soluble-type phosphate fertilizers to plants

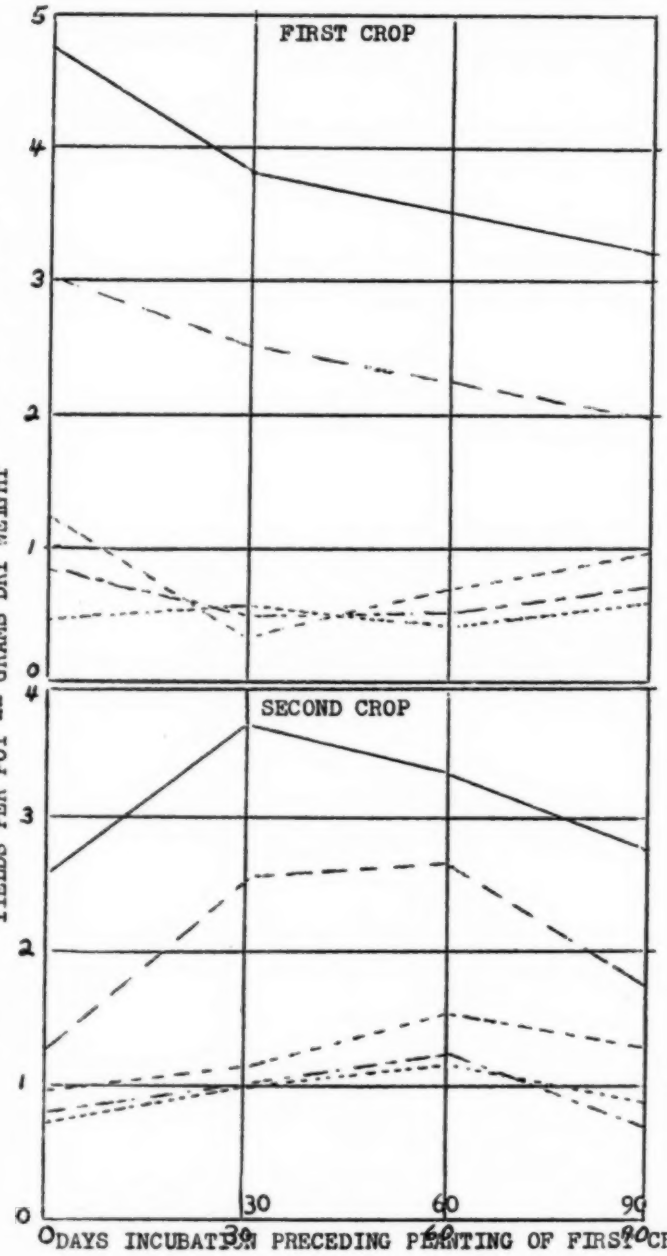


Figure 2.—Yield of romaine lettuce as influenced by certain phosphate carriers and incubation periods preceding planting.

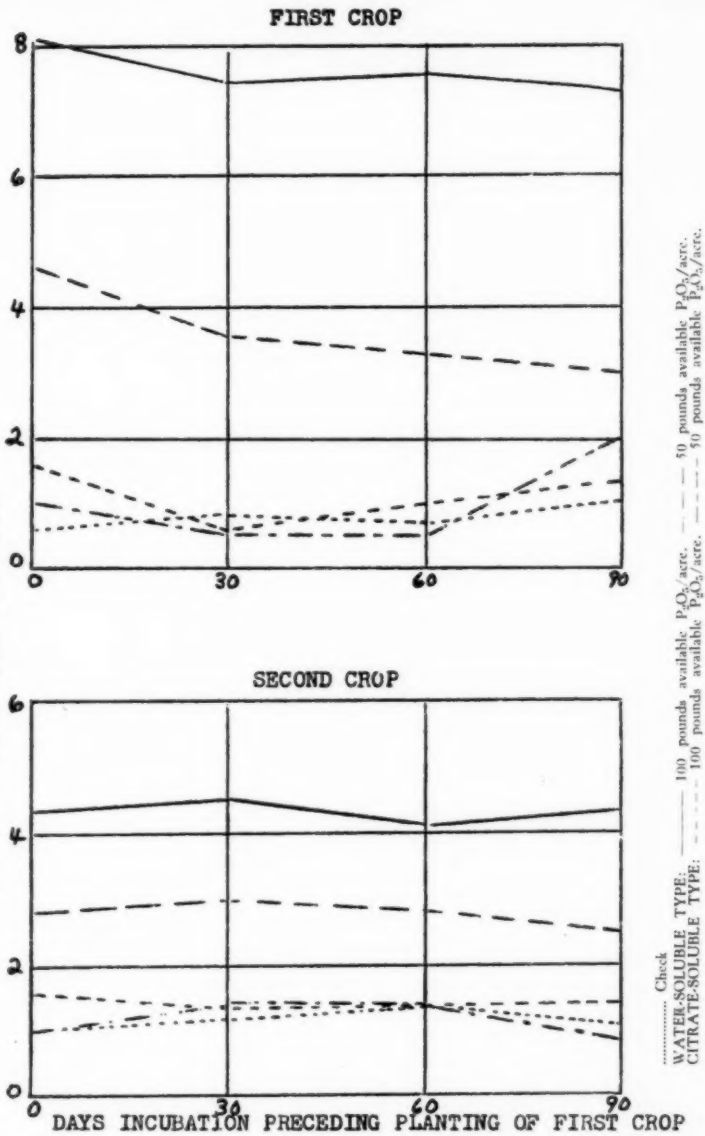


Figure 3.—Phosphorus uptake by romaine lettuce as influenced by certain phosphate carriers and incubation periods preceding planting.

already growing. This is shown by the response obtained when seedlings were transferred to those soils, to which water-soluble-type fertilizers had been added, at a time when no incubation had taken place. In this instance only was there a decided increase in weight of crop and phosphorus taken up by the plant (figures 2 and 3). However, in all cases where increased crop production occurred in the first crop due to this factor, there was a corresponding decrease in growth of the second crop, as compared with the 30-, 60-, and 90-day incubations.

The pounds per acre of available phosphorus, as shown by the carbon-dioxide method, when compared with the standards established, indicate that only a slightly greater amount of water-soluble-type fertilizers would have been needed in this soil to maintain a maximum level of crop production. This is substantiated further in the available levels produced and crop response obtained from the 50-pound additions, which indicate that slightly more than twice this amount would be necessary for maximum production. The results obtained in crop response and phosphate level from the addition of citrate-soluble-type phosphate fertilizers indicate that perhaps 15 to 20 times more than the 100-pound available $P_2O_5$ application would be required before good crop response could be obtained from these fertilizers. It is obvious that such additions would not be economically feasible.

## Summary

1. The use of water-soluble-type phosphate fertilizers results in the establishment of a much higher level of available phosphorus in calcareous soils than does the use of comparable quantities of citrate-soluble type of phosphate fertilizers.

2. When various types of phosphate fertilizers were added to calcareous soil an immediate reduction in availability took place. This reduction was practically completed in 24 hours and no further significant change took place over a 90-day incubation period.

3. The level of available phosphorus in the soil was altered by the addition of various rates of the water-soluble fractions of the phosphate fertilizers or by the removal of phosphate by crops.

4. The citrate-soluble-type phosphate fertilizers did not cause significant yield increases on calcareous soils nor did they increase the available phosphorus level in the soil.

5. The time of application of the water-soluble-type phosphate fertilizers was not important in calcareous soils when applied previous to planting crops. Some benefit was shown when available fertilizer was added during the early stages of growth.

6. So-called fixation or reversion of phosphate fertilizers in calcareous soils may not take place as such, rather the reduction in availability which

occurs when water-soluble-type phosphate fertilizers are added to these soils appears to increase the reserve of available soil phosphorus, resulting in the establishment of an equilibrium between the amount of phosphorus in the soil solution and that held by the soil itself.

Table 1.—Composition of fertilizers used.

| Material | Total $P_2O_5$ content (percent) | Available $P_2O_5$ (percent) | Available | | Equivalent rate per acre (pounds) | Manufacturer's guarantee analysis (percent) |
|---|---|---|---|---|---|---|
| | | | Water soluble (percent) | Citrate soluble (percent) | | |
| **Water-soluble availability type** | | | | | | |
| Single superphosphate | 19.9 | 18.9 | 87 | 13 | 556 | 18 |
| Treble superphosphate | 49.1 | 43.7 | 87 | 13 | 232 | 43 |
| **Citrate-soluble availability type** | | | | | | |
| Fused phosphate | 25.0 | 18.0 | 8.0 | 92 | 556 | 18.8 |
| Tricalcium phosphate | 42.9 | 13.4 | 9.0 | 91 | 752 | -- |

# Symptoms of Nutritional Disorders in Sugar Beets[1]

R. L. Cook[2]

A knowledge of symptoms of nutritional disorders is another very useful tool which may be used in soil-fertility control. The more commonly grown agricultural crops, including sugar beets, are normally green in color. Any other color is abnormal and unless insects or diseases are the cause it is very likely that the condition is due to faulty nutrition. It is true that unfavorable weather conditions may accentuate nutrient deficiencies and thus intensify the symptoms of deficiency but it is not correct to say that such abnormal colors as yellow or purple are "simply due to the weather."

When nutrients are lacking, most plants sooner or later become yellow. One must decide which nutrient is lacking from the pattern of yellowing and from the location of the leaves which first turn yellow. Sometimes the pattern may not be exactly characteristic and sometimes two elements may be contributing to the abnormal appearance. At such times confusion may be avoided by making use of chemical tests on either the soil or certain portions of the green plants. The chemical tests are also very useful in differentiating between abnormal appearances caused by nutritional deficiences and those caused by insects or diseases.

## Nitrogen Deficiency

Nitrogen exists in the soil largely as a constituent of organic matter. Through decomposition of the organic matter by soil organisms the nitrogen is changed into forms available to plants. The final product in the soil-nitrogen cycle is nitrate nitrogen. This is the form in which most plants prefer their nitrogen. Since the decomposition of the organic matter is dependent on the activity of living organisms, nitrogen availability in soil is influenced by temperature, moisture, and aeration.

This explains why sugar beets are often found starving for nitrogen on soils fairly well supplied with organic matter. This occurs during cold wet seasons, sometimes during periods of drought following a season of cold wet weather. The condition was strikingly illustrated in July and August of 1947 when beets on the Brookston soils of the Saginaw Valley and Thumb areas of Michigan were quite generally deficient in nitrogen. This was probably due largely to a lack of aeration caused by excessive compaction of the soil during the heavy spring rains.

[1]Contribution from the Soil Science Section, Michigan Agricultural Experiment Station, East Lansing, Michigan. Authorized for publication by the Director as journal article No. 950 n.s. of the Michigan Agricultural Experiment Station.

[2]Professor of Soil Science, Michigan State College.

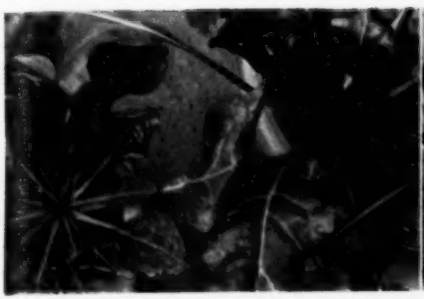

Figure 1.—Nitrogen deficiency causes very light-green to almost yellow leaves. The plant on the left was starved for nitrogen. Note the horizontal position of the leaves. The plant at the right received as ammonium nitrate all the nitrogen it needed.

Figure 2.—Sugar beets may obtain their nitrogen from decomposing alfalfa. In pot number 1 sugar beets were grown after corn which had followed alfalfa. In pot number 2 the sugar beets followed alfalfa directly. Notice the larger, greener, top growth. The lower leaves on the plants in pot number 2 were getting yellow when the picture was taken. The available nitrogen supply was evidently becoming exhausted. In pot number 6 the beets were grown after wheat, without a legume in the rotation.

Figure 4.—Sugar beets deficient in phosphorus grow slowly and are very dark green during the early part of the growing season. The leaves may or may not be fringed with red.

Figure 5.—In the later stages, phosphorus-deficient sugar beets become light green in color. The appearance at that time is suggestive of nitrogen deficiency. The green-tissue test may be necessary to avoid confusion.

As the soil nitrate supply becomes depleted the leaves become light green and eventually yellow as the deficiency becomes more serious. The loss of chlorophyl and the resultant yellowing occurs first on the older leaves and is uniform over the entire area of each leaf. This is an important point as in the yellowing caused by manganese deficiency, the veins and the leaf tissue close to the veins remain green. This gives the leaf a mottled appearance. Another characteristic of nitrogen deficiency is the direction in which the leaves grow out from the crown. Instead of standing erect as they do in a normal plant they grow out in a horizontal direction to give the beet the appearance of having been stepped on. This, together with the color difference, is illustrated by figure 1. An examination of figure 2 furnishes an opportunity to compare the appearance of beet leaves yellowed from three deficiencies—nitrogen, manganese, and potassium.

Where there is confusion between the three deficiencies, the green tissue test for nitrate nitrogen may be used to very good advantage. When the crop is growing rapidly, a *soil* test for nitrate is always low, as the plants take it up as fast as it is formed in the soil. Still there might be enough to satisfy the requirement of the plants. In other words, under those conditions, the soil test is not a true measure of the power of the soil to produce nitrate. A test of the green tissue, however, really shows whether or not the plants, at that particular time, are getting all they need.

Alfalfa as a green manure crop is a very good source of nitrogen for sugar beets. On tours of the sugar beet areas in early September it has been possible, usually, to tell from the color of the beet leaves the number of years that have elapsed since a field has produced alfalfa. Invariably the dark-green beets have been found in fields where the preceding crop was alfalfa or where but 1 year had elapsed since alfalfa was plowed under. Tissue tests on such fields have always indicated sufficiently high nitrate levels. Where the beets have showed distinct signs of nitrogen starvation, it has usually been found that the field had not grown alfalfa or clover for several years. An illustration of how alfalfa affects the appearance of sugar beets may be obtained from figure 3.

### Phosphorus Deficiency

Phosphorus is held in the soil in a highly immobile condition. A portion is absorbed by the clay and held in an exchangeable form ready for use by the plant upon contact by the roots. Some is held as slowly available iron and aluminum phosphates and some as available but insoluble calcium and magnesium phosphates.

As a result of this fixed condition of the phosphorus, plants are most likely to starve for phosphorus while they are small, before the roots become well established, and during cold wet periods when the roots are not growing or growing slowly. At such times the nutrient absorbing root surfaces are not being formed fast enough to contact a supply of phosphorus sufficient for the needs of the growing portions of the plant.

A deficiency of phosphorus delays the emergence of sugar beet seedlings and makes them less resistant to disease. Once the plants have emerged they grow slowly and become stunted. The stunted plants have small *dark-green* leaves which, in extreme cases, are fringed with red, as shown in figure 4. If the red color is present, the symptom is very reliable. If the red color is not in evidence it is well to make a tissue test for phosphorus. A low phosphorus test confirms the suspicion. Such leaves always test high in nitrate. The test should be made on the petioles of the older leaves.

The unusually dark-green leaves are the result of an extremely high nitrate content. When growth is held back because of a lack of phosphorus the plant takes in nitrate in excess (luxury consumption). The small green leaves on phosphorus-deficient plants stand more erect than on normal plants, as shown in figure 10. This is in contrast to the horizontal position of the light-green leaves on the nitrogen-deficient plant shown in figure 1.

After about the middle of the growing season, if phosphorus deficiency continues to be serious, the beet leaves gradually lose their dark-green color and finally become very light-green or yellow as shown in figure 5. The older leaves die and the condition very closely resembles nitrogen deficiency. Such plants will, however, have a high content of nitrate so the test is very useful in avoiding a mistake. During the latter part of the growing season it is always desirable to use the nitrate test to distinguish between these two deficiencies.

### Potassium Deficiency

Although the heavier soils, where sugar beets are most commonly grown, contain large quantities of potassium much of it is in mineral form and not readily available to plants. The potassium held by the clay and organic colloids, in the exchangeable form, and that continually being liberated in the decomposition of fresh organic matter furnishes most of that used by growing plants. Sugar beets do especially well on soils well supplied with organic matter. Perhaps the fact that they contain so much potassium, and so have need of a soil where the element is plentiful, is one of the reasons.

When the soil supply of available potassium becomes depleted, the oldest leaves are first affected. This is because of the translocation of potassium from the old to the new growing tissue. The leaves start turning yellow first at the tip and along the edges. Gradually the yellow area works toward the center of the leaf and the edge turns brown. Sometimes the chloratic area becomes yellowish gray rather than a distinct yellow as is characteristic of bean leaves yellowed by potassium starvation. The number 2 leaf shown in figure 2 was taken from a potassium-deficient sugar beet. Compare with it the leaves from nitrogen- and manganese-starved beets, shown in the same picture.

Tissue tests for potassium should be run on leaf petioles. In some cases it has been observed that plants showing slight-to-medium symptoms of

potassium starvation test low-to-medium in potassium. In other words, plants with such symptoms do not always test blank. This probably means that for maximum growth, sugar beet leaf petioles should contain potassium sufficient for a high test.

### Manganese Deficiency

The availability of manganese to growing plants depends, according to Sherman and Harmer, (2)[3] on the degree of oxidation of the manganese. Under alkaline conditions the oxidation-reduction equilibrium swings toward the manganic side and plants are unable to obtain manganese for normal growth.

Sugar beets are commonly grown in Michigan on neutral to alkaline soils. As a result, manganese deficiency is common. It is most severe on the soils of highest alkalinity, especially on highly alkaline sandy soils. The deficiency may appear in the plant at any time during the growing season and is first noticed as a mottling of the new growth. The green color gradually fades from the leaf tissue between the veins. The veins themselves and the area closely adjacent to the veins remain green for a considerable period after the rest of the leaf is yellow. The number 1 leaf shown in figure 2 is typical of beet leaves badly deficient in manganese. Sometimes the veins are much less distinct. In fact, it is occasionally difficult to distinguish the mottling. In such cases there is a possibility of confusion between manganese and nitrogen deficiency. Then one should resort to the use of the green-tissue test for nitrate nitrogen. This should be run on the leaf petiole. If the test is positive, it is safe to assume the yellowing to be due to something besides nitrogen deficiency. Whenever manganese deficiency is suspected it is always wise to determine the reaction of the soil. If the pH is above 6.8, manganese deficiency may be expected.

### Boron Deficiency

Boron is not plentiful in Michigan soils. However, the total quantity of boron in a soil is of little importance. The important consideration is the state of availability. In neutral or alkaline soils, availability is slow and on such soils sugar beets develop normally only if boron is applied as a fertilizer.

Boron deficiency of sugar beets has for many years been termed "heart rot." It was so called long before it was realized that a lack of boron caused the disease. Investigators in Germany and France spent many years trying to isolate an organism responsible for the death of the heart tissue. Of course, they were not successful and in 1931 Brandenburg of Germany showed that the disease could be prevented by adding soluble boron to the soil. Heart rot was observed in Michigan by Kotila (1) in 1934.

[3]The numbers in parentheses refer to literature cited.

There are several rather specific and different symptoms of boron deficiency which may or may not all occur on the same plant. Some plants may have both top and root symptoms while some may have top symptoms only, others may have only root symptoms.

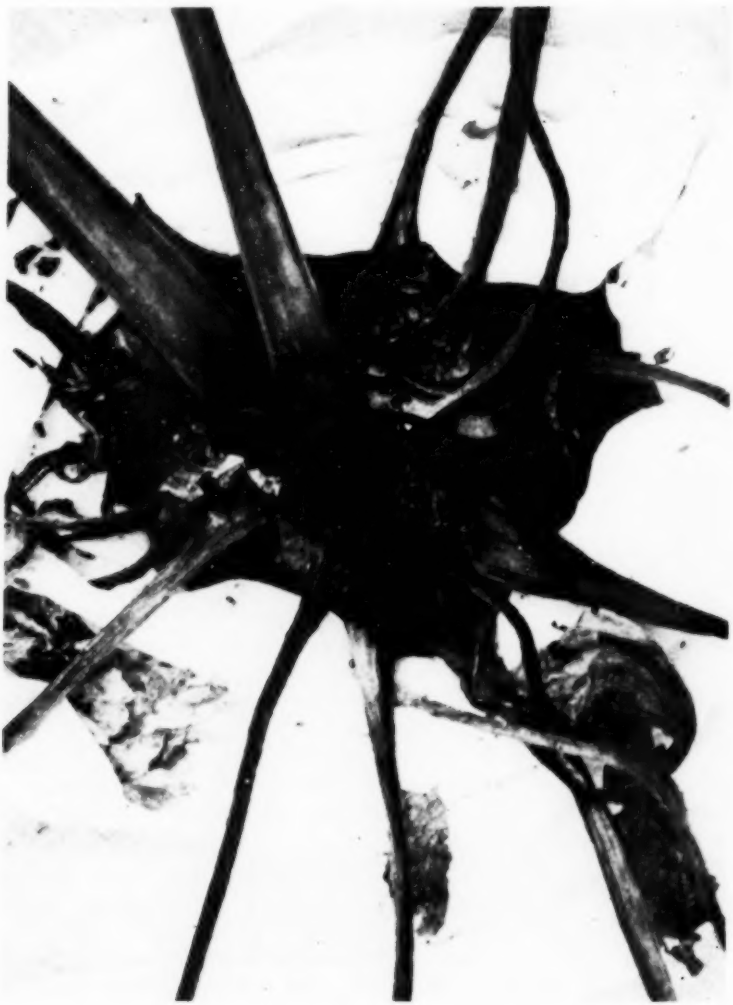

Figure 6.—Sugar beet deficient in boron. This plant illustrates the reason for calling the disorder "heart rot".

The most noticeable symptom is the dead heart illustrated by figure 6. This is first noticed during mid-summer, after the beet has attained considerable size. The leaves may all die. On severely affected fields the crop may be almost entirely defoliated by the end of the summer. Some beets actually die but most of them make new growth during the early fall months until new leaves, from around the edge of the crown, may almost cover the dead heart.

Perhaps the first symptoms of heart rot are cross-checked petioles and misshapen leaves, illustrated in figure 7. The leaves seem to grow unevenly on the two sides. This causes the petioles and midribs to twist and the leaf to develop only on one side. There is also a tendency, as shown in figure 8, for the development of a large number of small leaves, few of which ever reach normal size.

Boron-deficient beets also give one the impression of having been stepped on. They resemble nitrogen-deficient beets in this respect but differ from them in that the leaves are dark green rather than light green. After boron-deficient beet leaves start to disintegrate they turn yellow, brown, and black.

The roots of sugar beets affected by heart rot vary greatly in the extent to which they break down. In fact, some plants show by their leaves

Figure 7.—Boron-deficient sugar beet showing the cross-checked petioles and twisted, misshapen leaves.

that a deficiency of boron exists while their roots appear perfectly normal. Usually, however, the root tissue turns black and disintegrates to various degrees. In some cases the whole crown breaks down while in others the disintegration is scattered throughout the beet. When the disintegrated areas break through the surface they appear as external cankers. A good idea of the appearance of boron-deficient sugar beet roots may be obtained from figure 9.

Figure 8.—Many sugar beets deficient in boron develop a large number of small abnormally shaped leaves. There seems to be a tendency for the plant to try to cover the injured heart area with leaves. In such cases the leaves remain small.

Sugar beets are so sensitive to a deficiency of boron that in Michigan it is recommended that borax be included in the fertilizer for beets on all soils, although it is only on the alkaline soils that heart rot has been found serious. When the fertilizer is placed in bands beside the seed or in contact with the seed, the rate of application need be only 7 to 10 pounds per acre. More than that quantity may be toxic when placed in direct contact with seed.

### Sand Culture Experiments

Sand cultures have been used very advantageously in deficiency symptom studies. (3) In such experiments the importance of several other elements in the nutrition of the sugar beet has been demonstrated. Beets have

been grown in glazed pots filled with quartz sand, with all nutrients mixed with the sand as one treatment, and with single elements omitted as other treatments. A fairly good idea of the technique involved may be gained by examining figure 10.

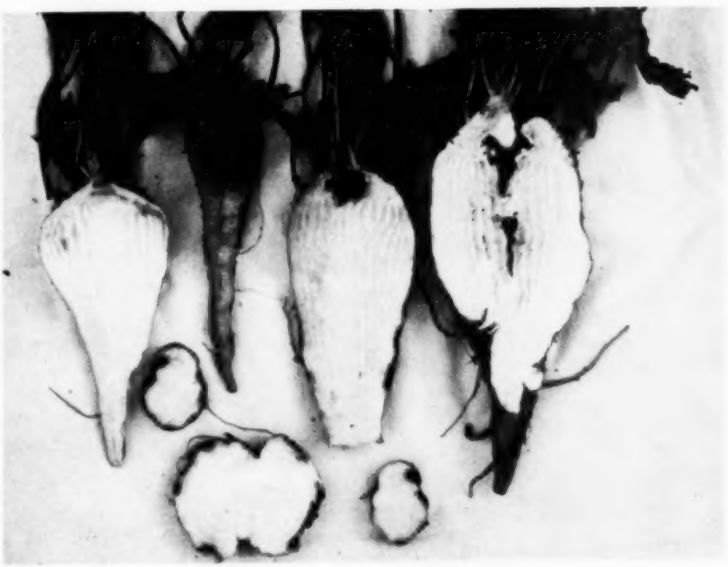

Figure 9.—Boron-deficient sugar beet roots. Notice the canker on the side of the whole beet, the blackened tissue in the left longitudinal section, and the dead hearts in the other two. The beets had attempted to cover the dead hearts with new growth. The three cross-sectional pieces were from beets with very bad cankers, places where the internal breakdown had broken through the epidermis.

## Calcium Deficiency

A complete lack of calcium in a sugar beet soil is just as detrimental to the growth of sugar beets as is an absence of potassium. This was proved in the experiment represented by the cultures shown in figure 10. In that experiment the plants which did not receive calcium would have died while very small had not a small amount of calcium been applied. After the small addition was exhausted the plants gave evidence of the fact by the death of the newest leaves as shown in figure 11. Apparently a continuous supply of calcium is always necessary in the growth of this plant. Perhaps that is an important reason why sugar beets do not do well on acid soils.

## Magnesium Deficiency

Magnesium deficiency in sugar beets has not been observed in the field but there is a possibility that under certain conditions such a deficiency

may occur. More research work with this element may reveal such conditions.

In sand cultures the omission of magnesium from the nutrient solution has resulted in plants similar to those produced in cultures where potassium was omitted except that in the case of magnesium deficiency necrotic areas appear throughout the entire area of the leaf, rather than just around the edge. An idea of the pattern may be obtained from an examination of figure 12.

Figure 10.—Sand cultures have been found very useful in studying deficiency symptoms. In such experiments the control treatment has included all essential nutrients mixed with the sand, called the complete treatment. The other treatments have been formed by omitting single nutrients.

## Iron Deficiency

In sand cultures a lack of iron has depressed sugar beet yields and resulted in a characteristic leaf chlorosis. The pattern is not unlike that displayed by other plants starving for iron—green veins on a very light-green to yellow background. This deficiency is also illustrated by figure 12.

## Summary

Undernourished plants indicate by their appearance that they are obtaining an insufficient supply of nutrients. It is normal for sugar beet leaves to be dark green. Any other color is abnormal and unless insects or diseases are the cause it is very likely that the condition is due to faulty nutrition, and not simply to adverse weather conditions.

Nitrogen-deficient sugar beet leaves are uniformly light green in color and they spread out in a horizontal direction. In the early stages of growth, phosphorus-starved sugar beets produce small dark-green leaves which may or may not be fringed with red. During the latter part of the growing season the leaves turn uniformly yellow if the supply of phosphorus remains inadequate. Where potassium is deficient in the soil the leaves turn yellow at the tips and along the edges. Necrosis then works in from the edge of the leaf toward the center. Magnesium-deficiency symptoms resemble those of potassium but the chlorosis and necrosis appear in spots anywhere on the leaves, rather than first along the edges.

Figure 11.—Calcium-deficient sugar beet. Note the dead center leaves. Calcium deficiency shows up in the new growth.

Manganese deficiency shows up as a yellowing of the leaves with the veins and sometimes the tissue close to the veins remaining green. Iron deficiency closely resembles manganese deficiency.

A lack of boron in the soil causes heart rot of sugar beets. The heart tissue dies and the root gradually disintegrates. Leaves develop cross-checked petioles and twisted midribs, with development faster on one side of the leaf than on the other.

Calcium deficiency resembles boron deficiency in that the new center leaves are affected but the heart tissue does not disintegrate.

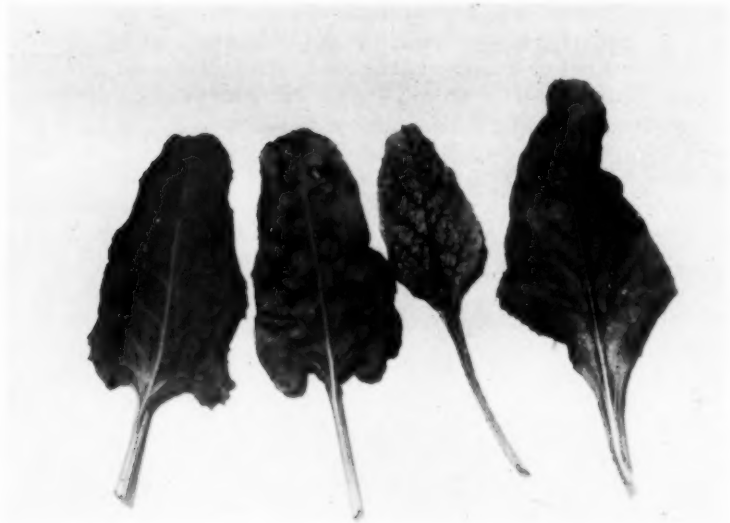

Figure 12.—A comparison of three deficiencies. Left, normal leaf. Next, magnesium deficiency. Note the necrotic areas throughout the leaf, also slight yellowing near the leaf margins. Third from left, iron deficiency. Veins very dark green and prominent against a yellow background. Right, manganese deficiency. Veins remain green but are less prominent than in the case of iron deficiency; gives leaf a mottled appearance.

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# The Relationship of Yield and Size of Beets to Sucrose Percentage of Beets Grown in Southern Alberta, Canada

K. W. Hill[1]

The existence of an inverse relationship between weight of beet and sucrose percentage seems to be generally accepted. Much research has been conducted to evolve agronomic practices which would increase the yield of beets without lowering the percentage of sucrose. Heretofore, no information has been available in regard to the correlation between yield and sucrose percentage of beets grown in Alberta but a deviation from usually accepted behavior has been suspected.

The Experimental Station at Lethbridge, Alberta, Canada, is approximately in the centre of the most northerly sugar beet producing area in North America. The latitude is 49° 42′ and the longitude is 112° 50′. The summer climate is characterized by very long days with warm to hot temperatures and cool nights. The average growing season has been 141 days.

During the 23 years since the establishment of the present sugar beet industry the consistently high percentage of sucrose in beets grown in this area has been apparent. In a previous publication (4)[2] the average yield of beets has been quoted at 12.18 tons per acre and the average percentage of sucrose at 17.85.

Brewbaker and McGreevy (1), working in Colorado, report significant correlations of $r = -.6310$ for an unselected population and of $r = -.1839$ for a selected group of beets. Cook et al (2) of Michigan observe that larger beets are generally recognized to be lower in sucrose percentage than are smaller beets. However, in Alberta it has been observed, as reported previously (4), that application of manure which increased the size of beets, did not depress the sucrose percentage, and also that plots of beets grown in rotational studies differed widely in yield but were similar, if not identical, in sucrose percentage. Furthermore, it has been observed that imported American varieties frequently have shown a higher percentage of sucrose under Alberta conditions than under the more southerly climate where they were developed. These apparent divergencies have prompted the present investigation.

## Materials and Methods

A random population of roots from each of four pairs of sugar beet plots growing in an experimental rotation was selected, weighed, and

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[2]The numbers in parentheses refer to literature cited.

analysed individually. This rotation has 2 successive years of beets following a manurial treatment. Triple superphosphate fertilizer has been applied each year at the time of seeding the beets. In an additional study several hundred selected roots from a breeding block of the Kuhn variety of beets were weighed and analysed individually. Correlations between weight and sucrose percentage were calculated for each plot of beets in the former and for each group of one hundred beets (in order of analysis) in the latter test. Similar correlations were calculated also for the total population of beets from each of the two tests.

In addition studies were made on the yield-sucrose percentage relationship of beets grown in a sweetclover rotation experiment. This rotation is of 4 years' duration and consists of beets, beets, wheat and sweetclover, and sweetclover summer-fallow. The sweetclover has been plowed under at various stages of growth or cut for hay. There were six different methods of handling the sweetclover in the summer-fallow year. Sugar beets have been grown after sweetclover summer-fallow and the next year beets have followed beets. Since the rotation is continuous, direct comparisons were available every year for yield and sucrose percentage between beets grown after sweetclover summer-fallow and beets grown after beets under the same fertility treatment.

## Experimental Results

The correlation coefficients and yield performance of beets from the four pairs of plots are presented in table 1.

**Table 1.—Average yield performance and correlation coefficients between weight and sucrose percentage of sugar beets grown under different fertility treatments at Lethbridge, Alberta.**

| Fertility treatments | Crop | Rep. | 10-year average | | Correlation coefficients | |
|---|---|---|---|---|---|---|
| | | | Yield per acre (tons) | Sucrose percentage | Calculated | 5 percent level |
| 30 tons manure and 100 pounds triple superphosphate per acre | First | 1 | 19.77 | 15.8 | —.186 | .304 |
| | | 2 | 18.84 | 15.7 | —.241 | .325 |
| | Second | 1 | 19.53 | 16.3 | —.393 | .273 |
| | | 2 | 19.11 | 16.2 | —.402 | .286 |
| 100 pounds triple superphosphate per acre | First | 1 | 13.87 | 16.0 | .090 | .273 |
| | | 2 | 11.74 | 15.5 | —.003 | .325 |
| | Second | 1 | 16.09 | 16.4 | —.145 | .325 |
| | | 2 | 16.01 | 16.0 | —.285 | .286 |
| For complete experiment | | | | | —.154 | .108 |

The data in table 1 indicate considerable variability between the correlation coefficients of the various groups. Only one pair of plots showed significant negative correlations between weight and sucrose percentage. In the remaining six plots the correlation coefficients varied from a non-significant positive value to a negative value which approached significance.

The correlation coefficients for a total of 800 selected roots and for each group of 100 comprising this total are presented in descending order of average weight of beet in table 2.

**Table 2.**—Average weight and sucrose percentage and the correlation between weight and sucrose percentage of eight groups of selected beets grown in a breeding block at Raymond, Alberta.

| Group | Mean weight (ounces) | Mean sucrose percentage | Correlation coefficients | |
|---|---|---|---|---|
| | | | Calculated | 5 percent level |
| 1 | 43.7 | 18.6 | —.400 | .197* |
| 3 | 42.9 | 18.0 | —.302 | .197 |
| 2 | 41.1 | 18.3 | —.405 | .197 |
| 4 | 37.6 | 17.3 | —.204 | .197 |
| 7 | 36.5 | 17.8 | —.153 | .197 |
| 8 | 36.5 | 17.3 | —.140 | .197 |
| 5 | 34.2 | 17.8 | —.061 | .197 |
| 6 | 33.9 | 17.6 | .001 | .197 |
| Total population | | | —.093 | .075 |

*Values are approximated by interpolation from Table 7.3 of "Statistical Methods", G. W. Snedecor, The Collegiate Press, Ames, Iowa, 1946.

The results presented in table 2 also are extremely variable. The correlation coefficients varied from —.405 to .001. In this experiment beets were selected on the basis of morphology and weight beginning on one side of a small field and continuing across. The group numbers in table 2 give the order in which the lots of 100 were analysed. In a general way they also indicate the position in the field from which the roots were selected (that is, groups 1 and 2 were adjacent). The field was considered to be very uniform. It will be noted that there were significantly negative correlations for four of the groups while the value for the other four groups were non-significant; three being negative and the remaining one positive.

Four years' results for the yields and sucrose percentages of the first and second crops of beets following sweetclover summer-fallow are presented in table 3.

Whereas the data in tables 1 and 2 dealt with the analyses of individual roots those in table 3 have been obtained from analyses of samples of populations of sugar beets grown under different fertility treatments. The four seasons selected include "high" and "low" sugar years (1942 and 1946, respectively) as well as years of average sucrose percentage. It will be noted that the mean yields for the first and second crops were 17.84 and 14.89 tons per acre, respectively. The difference between these means was statistically significant. However, there was no significant difference between the means of sucrose percentage for the first and second crops. This was true of each year as well as for the total of 4 years. Since the number of beets per acre in the first and second crops was of the same order it must be concluded that the large beets of the first crop were equal in sucrose percentage to the comparatively smaller beets of the second crop. This is not in agreement with the observations of Cook et al (2).

The difference in suitability of the land for the first and second crops of beets is thought to be made up of physical fitness as well as fertility

considerations. Sweetclover summer-fallow has left the soil in excellent tilth and apparently well supplied with readily available nutrients. The comparative deficiency in both of these factors is thought to be the reason for the yield reduction in the second crop of beets.

**Table 3.—Four years' results for yield in tons per acre and sucrose percentage of first and second crops of beets under six fertility treatments after sweetclover summer-fallow.**

| Year | Fertility treatment | First crop | | Second crop | |
|---|---|---|---|---|---|
| | | Yield | Sucrose percentage | Yield | Sucrose percentage |
| 1942 | 1 | 17.17 | 18.6 | 13.45 | 18.3 |
| | 2 | 14.41 | 18.5 | 14.31 | 18.1 |
| | 3 | 15.63 | 17.3 | 15.64 | 17.6 |
| | 4 | 15.39 | 17.5 | 14.54 | 18.8 |
| | 5 | 16.54 | 17.9 | 15.19 | 18.7 |
| | 6 | 15.64 | 18.2 | 14.39 | 18.2 |
| 1944 | 1 | 16.97 | 16.8 | 16.70 | 16.6 |
| | 2 | 18.29 | 18.5 | 16.01 | 17.6 |
| | 3 | 17.69 | 17.5 | 15.29 | 17.2 |
| | 4 | 19.11 | 18.1 | 18.29 | 17.6 |
| | 5 | 17.73 | 16.3 | 17.00 | 16.8 |
| | 6 | 19.25 | 17.0 | 16.60 | 17.4 |
| 1946 | 1 | 18.97 | 16.2 | 12.72 | 15.9 |
| | 2 | 18.37 | 16.8 | 12.42 | 15.0 |
| | 3 | 18.22 | 16.5 | 12.54 | 15.8 |
| | 4 | 18.32 | 16.0 | 11.54 | 16.0 |
| | 5 | 17.92 | 15.0 | 15.00 | 14.8 |
| | 6 | 15.40 | 15.3 | 11.14 | 15.7 |
| 1947 | 1 | 21.44 | 17.6 | 15.86 | 17.1 |
| | 2 | 20.49 | 17.8 | 15.92 | 17.0 |
| | 3 | 19.18 | 17.1 | 16.99 | 16.2 |
| | 4 | 17.58 | 16.9 | 16.57 | 16.7 |
| | 5 | 19.48 | 17.6 | 14.50 | 16.7 |
| | 6 | 19.01 | 17.3 | 14.67 | 17.4 |
| Means | | 17.84 | 16.5 | 14.89 | 16.9 |

## Discussion of Results

*Correlation between weight and sucrose percentage.*—A significant negative correlation between the weight and sucrose percentage of sugar beets usually is regarded as a maxim (1) (2).

It appears from table 2 that the larger beets in groups 1 to 4 were of such constitution as to display a significant negative correlation between weight and sucrose percentage, whereas the slightly smaller beets in the remaining groups failed to do so. It has not been possible to find an explanation for this behaviour. Since the general correlations (—.093 and —.154, respectively) for the two total populations discussed in tables 1 and 2, even though significant, were of much lower magnitude than usually reported for sugar beets (1) it is felt that the relationships between weight and sucrose percentage for these populations are not close and in fact the existence of a relationship of practical value may be questioned.

A regression coefficient of —.014 percent sucrose per ounce of weight has been calculated for the data summarized in table 2. This factor is so small in comparison with the experimental error that it is of negligible value in prediction.

According to table 3, under Alberta conditions a ton of beets from a field yielding 18 tons per acre may be expected to have as high sugar content as a ton of beets from a less fertile field yielding 15 tons per acre. If this apparent conclusion is real it is of great agronomic significance.

*Effect of climate.*—The climatic environment may be an influential factor in the yield-sucrose percentage relationship of beets grown in southern Alberta. Because of the northern latitude, the total hours of daylight during the summer months exceed most other beet-producing areas. The total hours of daylight (sunrise to sunset) for Lethbridge and Salt Lake City are compared by months in table 4.

**Table 4.—Total hour of daylight (sunrise to sunset) at Lethbridge and Salt Lake City during the summer months.**

| | May | June | July | August | Sept. | Total |
|---|---|---|---|---|---|---|
| Lethbridge | 477.9 | 488.7 | 492.1 | 447.4 | 378.3 | 2,284.4 |
| Salt Lake City | 448.2 | 451.0 | 457.5 | 427.0 | 374.1 | 2,157.8 |

Northern Colorado, northern California, and northern Ohio are approximately comparable in latitude to Salt Lake City.

Ulrich (5) has studied the conditions most favorable to the formation of sugar in the beet. The most favorable environment for the storage of sugar in the beet would embody intense sunlight, warm to hot days, and cool nights; this would allow for a maximum of photosynthesis with a minimum of respiration. The summer climate of southern Alberta satisfies this requirement quite well. The mean daily maximum and minimum temperatures for several beet-producing areas are compared with Lethbridge in table 5.

**Table 5.—Monthly averages of daily mean maximum and mean minimum temperatures in degrees Fahrenheit for several beet-producing areas of the United States compared with Lethbridge, Alberta.**

| | Lethbridge, Alberta | | Woodland, California | | Fort Collins, Colorado | | Salt Lake City, Utah | |
|---|---|---|---|---|---|---|---|---|
| Month | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. |
| May | 62.7 | 37.4 | 71.0 | 62.0 | 67.0 | 40.3 | 71.8 | 44.9 |
| June | 67.6 | 46.3 | 76.2 | 63.6 | 76.1 | 48.1 | 81.7 | 52.1 |
| July | 80.8 | 50.9 | 86.2 | 69.5 | 85.5 | 54.7 | 92.4 | 61.4 |
| August | 76.6 | 47.5 | 80.2 | 65.8 | 84.4 | 54.5 | 89.7 | 59.4 |
| September | 65.4 | 40.6 | 76.8 | 63.5 | 76.2 | 43.0 | 79.0 | 49.1 |

It will be noted that the climate of Lethbridge, Alberta, is characterized by both cooler days and cooler nights than the other beet-producing areas to which it has been compared in table 5. It is agreed generally that the rate of photosynthesis may be reduced if the temperature rises above 85 degrees to 95 degrees Fahrenheit. Hence, the extremely hot weather of some areas may have an inhibiting effect on photosynthetic activity.

## Summary

Correlation coefficients between weight and sucrose percentage are presented for several groups of individually analysed sugar beets. Compari-

sons are made also between the yield and sucrose percentage of sugar beets grown under different fertility treatments in a sweetclover-sugar beet rotation.

The correlation coefficients were extremely variable and less than half were significantly negative beyond the 5 percent level. Large beets were equal in sucrose percentage to small beets (with comparable stands) in the sweetclover-sugar beet rotation.

It is suggested that climate may be an important factor in the relationship which exists between yield and sucrose percentage in Alberta. Tables are presented which show the summer climate of Alberta to be characterized by more hours of daylight and cooler temperatures in comparison with several beet-growing areas of the United States.

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# Crop Rotation Practice in the Red River Valley

J. C. Tanner[1]

The Red River of the north constitutes the boundary between Minnesota and North Dakota, from the International Boundary on the 49th parallel of latitude, south for 187 miles. The valley through which this river flows ranges from 30 miles to 40 miles wide. At Grand Forks, North Dakota, which is centrally located in the valley, the average annual rainfall is 19.49 inches, and of this total approximately 65 percent falls during the 130-day growing season. Soils in the Red River Valley are black in color and range from medium to heavy clay types; and were originally very high in organic matter. However, continuous grain cropping has depleted the humus, with resulting loss of fertility. Water-holding capacity has been reduced and increase in wind erosion during the winter has increased, due to early farming practices.

Good soil management calls for definite but flexible crop rotations; rotations that include shallow and deep-rooted crops, intertilled row crops, grain crops, and legume crops, and a method of returning the maximum amount of organic matter to the soil. In the Red River Valley most crops are grown as cash crops and are not fed on farms. This system fails to produce sufficient farm manure to maintain soil fertility. Green-manure crops must then be used to fulfill the part of good soil management that calls for returning organic matter to the soil.

The basic crop rotation practiced by sugar beet growers in the Red River Valley is a 3- or 4-year rotation which uses the following sequence of crops: sweetclover sown with grain as a nurse crop, sweetclover summer-fallow, and sugar beets. The grain crop is the point of flexibility in this rotation. If a farmer does not have sufficient beet acreage for one-third of his farm land, he may extend this rotation into a 4- or 5-year rotation by increasing the years of a grain crop. The grain crop in the rotation is usually hard spring wheat or barley. When this rotation is extended into 4- or 5-years, the grain stubble is plowed and worked down in the fall immediately following threshing. This practice prevents the seeding of weeds in the stubble and conserves moisture for the following grain crop. For the green-manure summer-fallow year, a dwarf variety of either white or yellow blossom sweetclover is seeded with the grain crop in the spring. In the fall, the grain and sweetclover stubble catches and holds snow that will provide moisture for a rapid, heavy growth of sweetclover the following spring. The sweetclover crop is plowed under the following June, when it reaches the height of about 30 inches. After plowing, the fields are worked down by double discing and harrowing. This operation mulches

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and levels the soil, thus making an ideal seedbed for weed seed that was turned up by the plow. At this point in the rotation, many farmers level their fields with both home-made and commercial land levelers. The leveling operation also leaves a good seedbed for weeds. During the remainder of the summer and fall the summer-fallow field is worked with either a field cultivator or spring tooth from three to five times, depending on the weed growth started and the rainfall. At the last cultivation, the field is ridged at right angles to the prevailing winter winds. This ridging permits an even catch of snow and helps prevent wind erosion throughout the winter.

A few of the many advantages of the sweetclover summer-fallow year in a rotation are listed briefly:

1. Since the Red River Valley is located in a non-irrigated area of sub-marginal rainfall, moisture must be conserved throughout the crop rotation. The early summer plowing and subsequent tillings during the summer-fallow year keeps the top soil well mulched and holds moisture for the following beet crop.

2. The sweetclover summer-fallow year returns organic matter to the soil through the deep rooted, heavy growing sweetclover crop that decomposes readily when plowed under green. This legume crop increases the soil fertility, not only by fixing free nitrogen from the air, but also by increasing the supply of organic matter.

3. The summer-fallow method actually prepares a seedbed for weeds to grow in, and after a weed crop is started it is destroyed by complete mechanical cultivation. This is a very inexpensive method of cleaning weeds out of a field, since no hand labor is required. The beet crop following the summer-fallow is relatively free from weeds, a condition which is necessary to make complete mechanization of sugar beet growing a success.

4. Sweetclover summer-fallow puts land in first-class condition for early preparation for beet planting in the spring. Early planting is very important, because of the short growing season in the Red River Valley. In the spring preparation, a summer-fallow seedbed can be worked very shallow, which helps conserve the surface moisture for germination and does not bring up deep buried weed seed.

5. The crop rotation that includes sweetclover summer-fallow enables farmers to handle large acreages more efficiently with less equipment and labor, as summer-fallow work does not come during the rush season of planting and harvesting.

All successful crop rotations in the Red River Valley revolve about the sweetclover summer-fallow year. In this one season the farmer increases organic matter and available nitrogen, and kills many weed crops. With the application of normal amounts of high analysis phosphate fertilizer at beet planting time, a profitable beet crop is almost a certainty. Since over 95 percent of the beet tops are returned to the soil, this helps to maintain the organic matter of the land.

The beet crop answers all the demands of a good soil management program. It furnishes an intertilled row crop, and a deep-rooted crop. It also helps to maintain soil fertility, since over 95 percent of the beet tops are returned to the soil. Dunn and Rost (1), using commercial fertilizer prices of June 1946, report that the value of tops from a 15-ton beet crop are worth $21.94 per acre when used as green-manure. This green-manure readily decomposes and makes available plant foods for the crop which follows the sugar beet crop.

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# The Effect of Temperature Upon the Growth and Yield of Sugar Beets

L. T. Pierce[1]

Material presented in this paper represents conclusions drawn from three seasons' collection of temperature and sugar beet growth data in the Yellowstone Valley near Billings, Montana. The initial objective of this project was to establish the form of the growth rate curve with respect to temperature, and to devise therefrom a method whereby early and mid-season temperatures might be used to predict the final yield in the fall. While results of this study are not conclusive in all respects, a reasonably satisfactory growth rate curve for sugar beets has been established, and a new method of predicting final yield in eastern Montana is being advanced In addition, a substantial volume of reliable growth data has been accumulated, and will be made available to others who have a need for it.

It has long been known that plants grow more rapidly in warm than in cool weather. Brandes and Coons (1)[2] found that sugar beets are grown most profitably in regions having a mean summer temperature between 67 and 72 degrees. Furthermore, it is common knowledge that July and August are the months in which beet tonnage is made. Knowing this general relation between temperature and growth, then, numerous attempts have been made to establish a practical working formula based upon temperature records which might be used to predict final yield at some convenient date in spring or summer. The most successful work along this line was done by Swift and Cleland (5), who found a reliable correlation between annual yield in western Montana and the average temperature of the preceding cold season. A similar, but less satisfactory relationship, was established in 1944 by Pierce, Bush, and Wood (3) between yield and average June temperature. Realizing that a fully satisfactory solution to this problem in the Billings district must await the accumulation of more accurate knowledge concerning the way in which growth is related to the level of temperature, the author, in collaboration with R. R. Wood of the Great Western Sugar Company, set up a project in 1945 near Billings for actually measuring the growth of beet roots and relating it to the prevailing level of temperature.

## Materials and Methods

Growth and temperature measurements were made during the 1945, 1946, and 1947 growing seasons, starting about July 1. Test plots during these 3 years were located in fields adjoining one another at a point about 4 miles up the valley from Billings. The level of fertility in these three

[1]Meteorologist, U. S. Department of Commerce, Weather Bureau, Billings, Montana.
[2]The numbers in parentheses refer to literature cited.

fields was about the same, and definitely above the district average as reflected in yields.

Instrumental equipment included a conventional air thermograph, exposed in the usual Weather Bureau shelter, a soil thermograph with the element buried directly beneath one row of beets at a depth of 8 inches, and about 25 root measuring devices attached at the maximum diameter to randomly selected roots. A sketch of this device is shown in figure 1. It consists of a 2-foot length of oiled silk fishline, marked in inches with India ink, a 4-inch section of small diameter glass tubing, and a test tube, assembled as shown in the sketch. One end of the line was attached to the outer end of the glass tube, extended around the root, then passed up through the glass tube and into the test tube where the excess was coiled. As growth proceeded, the line was drawn out and weekly circumference measurements were read with reference to an index mark etched on the glass tube 2 inches from its outer end. All readings were made once a week, the instruments were checked for accuracy, and weekly temperature averages were computed from daily values. Thus this basic data were available in the form of weekly circumference increase, together with air and soil temperature as summarized in table 1. A preliminary report of this same project was presented before this Society at its 1946 General Meeting in Denver (4).

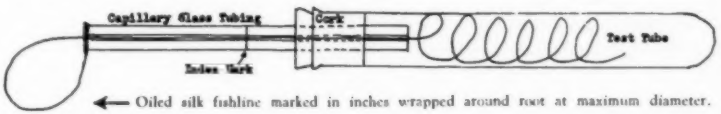

Capillary Glass Tubing
Cork
Test Tube
Index Mark
Oiled silk fishline marked in inches wrapped around root at maximum diameter.

Figure 1.—Sketch of beet measuring device.

## Results

The general relationship between temperature and weekly growth is best shown in graphical form. Figure 2 illustrates the seasonal variations in growth rate together with average soil temperature for 1945, 1946, and 1947. Growth here is expressed in terms of weekly circumference increase. The parallelism between these curves is quite striking, but is to be expected because of the normal seasonal variation in both temperature and growth. However, I submit that growth normally varies in such a manner primarily because of the seasonal march in temperature. It is significant, however, that practically all increases in temperature from week to week are accompanied by corresponding increases in growth rate, and vice versa. The most obvious exception to this is seen in the week of July 27 on the 1946 chart, when a decided slump in growth occurred following a hail storm on July 17. The subject of hail damage will be mentioned briefly later on.

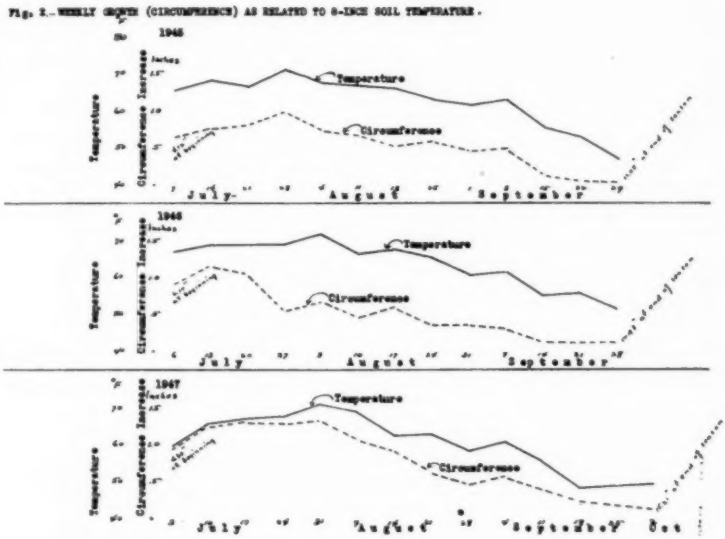
Figure 3 shows the same data converted to tons-per-acre increments and plotted in the form of a scatter diagram so as to show the relative growth rate with respect to temperature. Solid lines are regression curves

Table 1.—Average temperature and weekly growth data.

| 1945 | | | | | | 1946 | | | | | | 1947 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Average temperature | | Increase | | | | Average temperature | | Increase | | | | Average temperature | | Increase | |
| Date | | Air | 8-inches Soil | Circumference[1] | Tons per acre[2] | Date | | Air | 8-inches Soil | Circumference[1] | Tons per acre[2] | Date | | Air | 8-inches Soil | Circumference[1] | Tons per acre[2] |
| July | 7 | 64.4 | 65.5 | .66 | .653 | July | 6 | 68.3 | 67.2 | .99 | 1.284 | July | 3 | 59.3 | 59.2 | .92 | .456 |
| | 14 | 69.1 | 68.7 | .76 | .911 | | 13 | 70.0 | 68.7 | 1.16 | 1.865 | | 10 | 71.5 | 65.7 | 1.28 | .822 |
| | 21 | 71.4 | 66.8 | .81 | 1.313 | | 20 | 70.0 | 68.9 | 1.07 | 2.074 | | 17 | 72.4 | 67.0 | 1.30 | 1.098 |
| | 28 | 74.8 | 70.8 | .98 | 1.764 | | 27 | 70.6 | 68.7 | .56 | 1.223 | | 24 | 71.1 | 67.4 | 1.29 | 1.376 |
| August | 4 | 73.4 | 67.8 | .73 | 1.526 | August | 3 | 73.0 | 71.2 | .67 | 1.592 | | 31 | 73.2 | 70.4 | 1.34 | 1.702 |
| | 11 | 71.1 | 66.4 | .68 | 1.598 | | 10 | 66.0 | 66.4 | .45 | 1.129 | August | 7 | 72.9 | 69.0 | 1.09 | 1.648 |
| | 18 | 69.6 | 66.0 | .54 | 1.410 | | 17 | 61.1 | 67.4 | .58 | 1.583 | | 14 | 66.0 | 62.8 | .93 | 1.566 |
| | 25 | 63.6 | 63.2 | .60 | 1.726 | | 24 | 69.5 | 65.8 | .37 | 1.059 | | 21 | 69.0 | 63.0 | .64 | 1.179 |
| Sept. | 1 | 64.9 | 61.4 | .46 | 1.368 | | 31 | 59 4 | 61.2 | .36 | 1.098 | | 28 | 62.9 | 58.6 | .49 | .966 |
| | 8 | 68.2 | 62.6 | .48 | 1.548 | Sept. | 7 | 61.4 | 60.8 | .32 | .987 | Sept. | 4 | 68.1 | 60.2 | .59 | 1.237 |
| | 15 | 57.6 | 55.6 | .13 | .424 | | 14 | 57.0 | 55.4 | .13 | .392 | | 11 | 61.6 | 56.0 | .41 | .885 |
| | 22 | 47.4 | 52.6 | .06 | .221 | | 21 | 56.5 | 55.6 | .12 | .408 | | 18 | 51.2 | 48.9 | .27 | .578 |
| | 29 | 44.8 | 47.3 | .02 | .077 | | 28 | 53.2 | 51.6 | .10 | .330 | | 25 | 53.3 | 49.6 | .22 | .501 |
| | | | | | | | | | | | | October | 2 | 52.2 | 49.7 | .14 | .347 |

[1]Actual measurements.
[2]Adjusted to average field yield: 1945, 16 tons per acre; 1946, 18 tons per acre; 1947, 15 tons per acre.

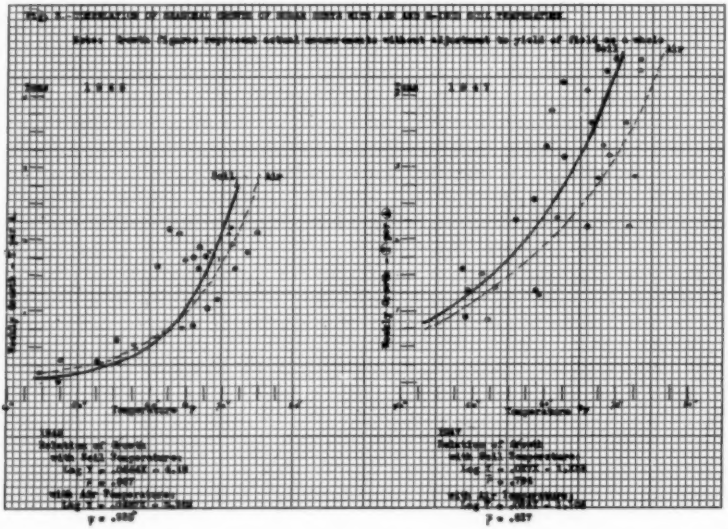
relating growth with soil temperature for 1945 and 1947, while dashed lines represent air temperature. Solid dots are used for soil, and open circles for air temperature. Curvilinearity of the relationship as plotted suggested use of a regression equation of the form log $Y = a + bX$; and individual equations are quoted in each case, together with the computed indices of correlation. Rho values for 1945 data are 0.887 and 0.927, respectively, for soil and air temperature; while the corresponding figures for 1947 are 0.794 and 0.841. All are well above the 1 percent level of significance, the figures being 0.684 and 0.661, respectively, for 1945 and 1947 data.




*Conversion to Tons per Acre.*—Growth was measured throughout this project in terms of circumference increase at the maximum diameter, which necessitated conversion into weights for reasons of convenience. The following regression equation, derived from weight and circumference measurements at harvest time was used for this purpose: log $W = 2.355$ log $C—2.259$. While this formula yields a fairly good representation of weight increments, it cannot be strictly accurate because it assumes that the roots maintain a constant shape throughout the season, while it is known that they change shape gradually as the growth proceeds. Having no usable information about this progressive change, however, it was necessary to base the conversion formula upon measurement of mature samples which included a wide variety of shapes.

Generally speaking, increases in linear measurements, such as circumference, bear a closer relation to soil than to air temperature, correlation

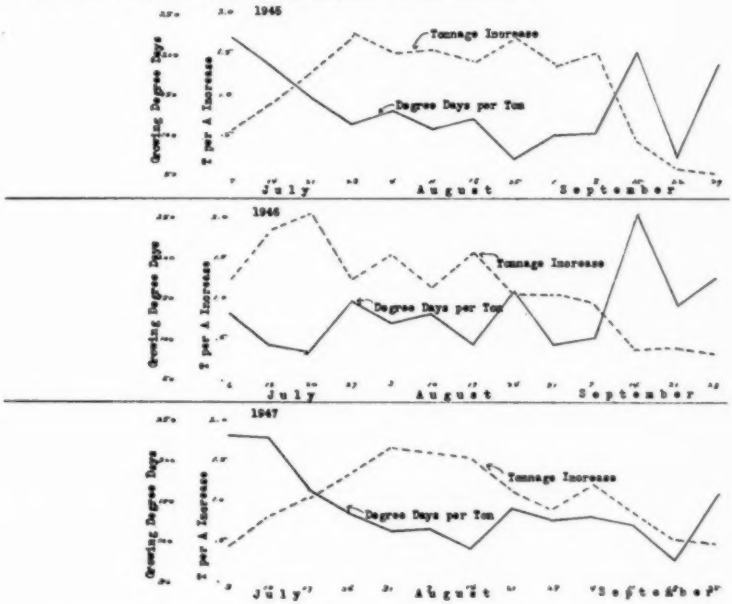
indices being 0.917 in 1947 and 0.957 in 1945, compared with 0.868 and 0.894, respectively, for air temperature. When increments are expressed in terms of weight, however, the correlation is higher with air than with soil temperature. This shift comes about as a result of the curvilinear relation between linear and volumetric measurements of the roots. The index of correlation between air temperature and tons-per-acre increase for example, is 0.920, compared with 0.887 for soil temperature. This seems to indicate that it is quite as satisfactory to use air temperature for this type of work as soil temperature, and it surely is much easier to measure.



*Estimated Hail Damage in 1946.*—No detailed correlation has been shown for 1946 data because of the hail storm which interrupted the normal growth pattern on July 17. However, this accident did provide an opportunity to estimate the loss caused by the hail, which at the time was thought to be about 20 percent. Reconstruction of the growth rate curve on the basis of the temperature relationship established in 1945 and 1947 gives a hypothetical final yield of 26 tons per acre in 1946, compared with the actual field average of 18 tons. This represents a paper loss of 31 percent which appears to be too high since the 18-ton yield exceeded the average for the factory district by a comfortable margin. Had hail not occurred, something else would likely have served as a limiting factor. This high production in spite of hail damage may be partly explained by the fact that the weight of roots in the ground on July 17 had already attained 8¼ tons per acre.

*Heat Requirements.*—So far as I know, the heat requirement of growing beets has not yet been established—neither has a standard heat unit been settled upon. I have, therefore, used a form of "growing degree day," which is simply the average daily temperature minus 45 degrees. This figure is logical because 45 degrees is close to the lowest limit of growth. Weekly or monthly "growing degree days" can be readily computed by subtracting 45 from the mean temperature for any time interval and multiplying by the number of days. This method can be used directly so long as daily values are all above 45 degrees; and a simple correction can be used if any daily averages below 45 degrees are encountered.

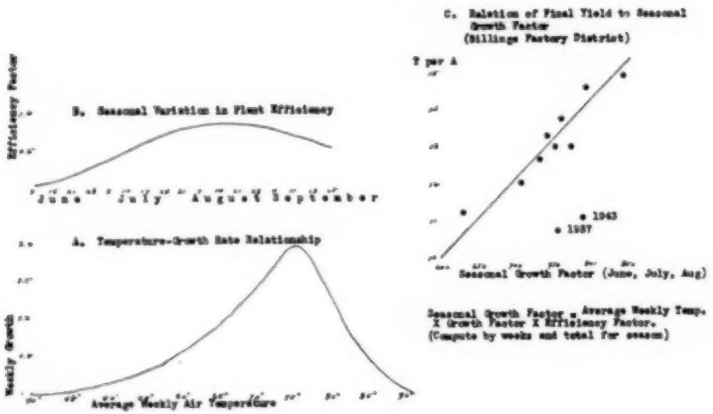
Fig. 4 NUMBER GROWING DEGREE DAYS REQUIRED TO PRODUCE 1 TON OF SUGAR BEETS




"Growing degree days" obtained in this manner were computed for each week during the three seasons beginning with July 1, and from these results the number of such heat units required to produce a ton of beets was obtained for successive weekly intervals. These figures are quoted in table 2 and are shown in figure 5-B plotted on a time scale for the 3 years. It should be noted that this curve is plotted from the last columns of table 2, headed "Tons per 100 DD." From this chart, it is seen that less heat is required to grow a ton of beets during the 6 weeks from late July to early September than during earlier or later weeks. During the early part of the season the plant is engaged in assembling the production machinery in the

form of leaves and a root system; hence it cannot attain full efficiency as a producer of root tonnage until about the middle of July. Peak efficiency, then, is maintained until about the first week of September, when gradual deterioration sets in, and efficiency drops because of shortages in raw materials such as duration of sunshine, favorable temperatures and available plant nutrients. During the first 3 weeks of July an average of 166 "growing degree days" are required to produce a ton of beets, and in the last 3 weeks of September the requirement is 156; while the average for the 7 weeks between late July and early September was only 118, with individual weeks below 100.

Fig. 5 METHOD OF COMPUTING FINAL YIELD FROM TEMPERATURE DATA




*Practical Applications.*—As previously stated, one of the initial objectives of this project was to devise a method whereby final tonnage yield might be predicted on the basis of the seasonal temperature record. Such a method has been developed which, while it may not exceed in accuracy the preharvest sampling procedure now in use, can at least be used as a convenient check. This method involves computation of weekly mean temperatures, and their adjustment by two factors representing the growth rate at specific temperature levels, and the efficiency of the plant on successive dates.

The curve shown in figure 5-A represents the manner in which sugar beet growth varies with temperature, and is based mainly upon results of the present study. The descending portion of this curve, however, is based upon studies made by B. S. Pickett (2), working in Texas with red beets. Mr. Pickett quotes 68.6 and 73.4 degrees F., respectively, as optimum

**Table 2.**—Relation between number "growing degree days" and tons-per-acre increase.

| 1945 | | | | | | 1946 | | | | | | 1947 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | | No. DD | Tonnage increase[1] | DD per Ton | Tons per 100 DD | Date | | No. DD | Tonnage increase[1] | DD per Ton | Tons per 100 DD | Date | | No. DD | Tonnage increase[1] | DD per Ton | Tons per 100 DD |
| July | 7 | 144 | .65 | 222 | .45 | July | 6 | 169 | 1.28 | 132 | .758 | July | 3 | 105 | .46 | 230 | .438 |
| | 14 | 169 | .91 | 186 | .538 | | 13 | 174 | 1.86 | 93 | 1.069 | | 10 | 188 | .82 | 229 | .436 |
| | 21 | 191 | 1.31 | 146 | .686 | | 20 | 175 | 2.07 | 85 | 1.182 | | 17 | 185 | 1.10 | 168 | .594 |
| | 28 | 208 | 1.76 | 118 | .847 | | 27 | 180 | 1.22 | 148 | .678 | | 24 | 186 | 1.38 | 135 | .742 |
| August | 4 | 198 | 1.53 | 129 | .769 | August | 3 | 194 | 1.59 | 122 | .820 | | 31 | 197 | 1.70 | 116 | .863 |
| | 11 | 178 | 1.60 | 111 | .899 | | 10 | 146 | 1.13 | 129 | 1.142 | August | 7 | 195 | 1.65 | 118 | .846 |
| | 18 | 174 | 1.41 | 123 | .811 | | 17 | 155 | 1.58 | 98 | .620 | | 14 | 147 | 1.57 | 94 | 1.068 |
| | 25 | 130 | 1.73 | 75 | 1.330 | | 24 | 174 | 1.06 | 164 | 1.548 | | 21 | 170 | 1.18 | 145 | .694 |
| Sept. | 1 | 138 | 1.37 | 101 | .993 | | 31 | 104 | 1.10 | 95 | .864 | | 28 | 124 | .97 | 128 | .781 |
| | 8 | 162 | 1.55 | 105 | .950 | Sept. | 7 | 102 | .99 | 103 | .970 | Sept. | 4 | 163 | 1.24 | 132 | .760 |
| | 15 | 85 | .42 | 202 | .694 | | 14 | 102 | .39 | 262 | .382 | | 11 | 108 | .88 | 122 | .815 |
| | 22 | 16 | .22 | 72 | 1.374 | | 21 | 60 | .41 | 146 | .683 | | 18 | 45 | .58 | 78 | 1.288 |
| | 29 | 15 | .08 | 187 | .533 | | 28 | 59 | .33 | 179 | .559 | | 25 | 78 | .50 | 156 | .691 |

[1]Increase adjusted to agree with final yield for the field: 1945, 16 tons; 1946, 18 tons; 1947, 15 tons.

growing temperatures for Crosby Egyptian and Early Wonder varieties, respectively; and 86 degrees F., as the absolute upper limit of growth. These figures have been adjusted upward for sugar beets on the basis of observation and estimate to 75 and 92 degrees, respectively. Growth in this figure is expressed in tons per acre per week, adjusted to an arbitrary final yield of 15 tons per acre. The efficiency factor, figure 5-B, although it is dimensionless in the chart, actually represents the number of tons increase per acre per 100 "growing degree days" at successive stages during the season. This chart runs from June 1 to September 25, but for predictive purposes September figures were omitted.

The procedure followed in arriving at a yield prediction was first to adjust each average weekly temperature for growth rate, multiplying by a factor extracted from the first curve 5-A, and then to make a second adjustment for plant efficiency, multiplying by the seasonal factor taken from the curve in 5-B. The final products, which I have chosen to call "weekly growth factors" were then totaled for each season from 1936 through 1947 and plotted against actual yield in figure 5(c). Of the 12 years considered, only 1937 and 1943 failed to fall in line. Yield in both of these years was unusually low due to serious hail damage, flood, frosts and other well-recognized reasons.

The period included in these summations extended from June 1 to August 31 only, in order that a prediction of final yield might be made sufficiently early in the season to be of practical value. The average error in estimating yield as of September 1 for the 10 years (1937 and 1943 being omitted) was .34 ton, and it is likely that if needed, a fairly reliable estimate could be made a week earlier. Temperatures in this case were taken from Airport Weather Bureau records at Billings—400 feet above the valley floor. Yields used were Billings Factory District averages, the district extending from Columbus to Forsyth, Montana, in the Yellowstone Valley.

The most attractive feature of this method of prediction is that it requires only that temperature records be maintained at some representative location in the area, to provide data from which the yield may be estimated with the aid of tables constructed from the three correction curves shown. Figure 5 is strictly applicable of course, only to the Billings area, but the curves could be adjusted to serve in other regions without too much trouble.

## Summary

Results of this study may be summarized under the following items:

1. A high correlation has been shown to exist between growth rate of sugar beets and the level of temperature.

2. There is no significant advantage of soil over air temperature as an indicator of growth rates.

3. "Growing degree days" computed on a 45-degree base is suggested as a convenient means for expressing the amount of heat available for crop growth in any season.

4. The efficiency of the plant in producing root growth varies significantly from week to week, reaching a peak during the period from late July to early September, and may be expressed as the number of "growing degree days" required to produce a ton of beets, or the number of tons produced per unit "growing degree days," each being the converse of the other.

5. A new method of predicting final yield on September 1 is proposed. Weekly "growth factors" may be computed by multiplying average weekly temperatures first by a temperature-growth factor, then by an efficiency factor, and totaling to obtain a "seasonal growth factor," which correlates well with final yield.

6. A substantial volume of reliable growth measurements has been accumulated, which will be made available to others having need for such data.

*Further Research Needed.*—The author is convinced that further experimental work is required to supplement information presently available, as follows:

1. To verify the temperature-growth rate curve presented herewith and determine whether critical temperatures have been correctly established, also to find whether or not it is applicable in other parts of the country.

2. To develop a more accurate seasonal conversion factor for translating linear root measurements into terms of weight. This requires more definite information regarding the manner in which roots change shape as growth proceeds.

3. To establish the effect of sunshine intensity and length of day upon growth rate.

4. To determine more accurately the nature of progressive changes in the ratio of tops to roots throughout the growing season.

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# Comparison of Various Chloride and Sulfate Salts as Fertilizers for Sugar Beets

R. R. Wood and R. T. Nelson[1]

Early studies in plant nutrition generally upheld chlorine as an unessential element in spite of its presence as chlorides in practically all plants. Subsequent investigations have indicated that the results one might get with chlorides will be dependent to no small extent on the plant under consideration. Sugar beets are among the crops which have appeared to use chlorides to some advantage (4)[2]. Other studies reported (1,2,3) have shown definite response of sugar beets to sodium chloride applications. However, in these studies little significance was given the chloride ion and the responses were generally credited to the cation or sodium element.

An analysis of cosettes from six factories of The Great Western Sugar Company in 1945 revealed that the chloride content of beets in the Lovell, Wyoming, district was distinctly low in comparison with beets from other factory districts in northern Colorado and Nebraska. At Lovell the percentage of chloride in beets was 0.0228 compared with an average at the other locations of .0591 or approximately 2½ times as much as at Lovell. In 1946, sodium chloride was applied to beets at the rate of 70 pounds per acre in the Powell area of the Lovell district. Application was by solution in irrigation water to 12-row strips. There was some indication in this test of a possible increase in tonnage resulting from the sodium chloride application, but the results were not conclusive and further study was deemed desirable. The results of experiments conducted in 1947 are reported here.

## Design of Experiments

Four tests were planted, three of which were harvested experimentally. The design used was a randomized complete block with six replications of each of nine treatments. The salts used were of high purity and the rates per acre were adjusted so that each treatment represented an equivalent quantity of salt based on their equivalent molecular weight. Application was by side dressing with Planet Jr. hand drills the second week of July. A calculated amount of each salt was weighed for each plot and all of that quantity applied to the plot. Plots were 6 rows wide x 28 feet in length. Four center rows, 25 feet in length, were harvested from each plot for yield, October 13-15, and one row was analyzed for sugar content.

A distance of 25 feet was allowed between series to prevent carry-over of salts between plots by irrigation water, but observations during the

[1]Agronomist, The Great Western Sugar Company, Billings, Montana, and Agronomist, The Great Western Sugar Company Experiment Station, Longmont, Colorado, respectively.

[2]The numbers in parentheses refer to literature cited.

season would indicate that this precaution was probably not necessary and only served to increase variability by spreading the plots over a greater area in the field.

## Results and Discussion

The treatments and rates per acre are given with the harvest results for three respective locations in tables 1, 2, and 3.

**Table 1.**—Summarized results, salt study, Laurel, Montana, 1947.

| Treatment description and rates per acre | Roots per acre (tons) | Sugar content (percent) | Gross sugar per acre (pounds) | Beets per 100 feet (number) |
|---|---|---|---|---|
| 300 pounds sodium sulfate ($Na_2SO_4$) | 19.42 | 17.24 | 6696 | 104 |
| 367 pounds potassium sulfate ($K_2SO_4$) | 18.09 | 17.14 | 6201 | 94 |
| 312 pounds potassium chloride (Kcl) | 19.51 | 17.44 | 6805 | 103 |
| 245 pounds sodium chloride (Nacl) | 18.24 | 17.38 | 6340 | 93 |
| 226 pounds ammonium chloride ($NH_4cl$) | 19.26 | 16.54 | 6371 | 99 |
| 279 pounds ammonium sulfate ($NH_4)_2SO_4$) | 17.62 | 16.20 | 5709 | 97 |
| 156 pounds potassium chloride and 122 pounds sodium chloride | 17.62 | 17.50 | 6167 | 97 |
| Check—no treatment | 18.27 | 16.84 | 6153 | 98 |
| Machine check—drill run empty over plot | 16.07 | 16.88 | 5425 | 91 |
| General mean | 18.23 | 17.02 | 6207 | 97 |
| CV (percent) | 10.87 | 4.17 | 11.64 | -- |
| F value | NS | NS | NS | |

**Table 2.**—Summarized results, salt study, Powell, Wyoming, 1947.

| Treatment description and rates per acre | Roots per acre (tons) | Sugar content (percent) | Gross sugar per acre (pounds) | Beets per 100 feet (number) |
|---|---|---|---|---|
| 300 pounds sodium sulfate ($Na_2SO_4$) | 20.83 | 17.38 | 7241 | 73 |
| 367 pounds potassium sulfate ($K_2SO_4$) | 21.53 | 17.20 | 7406 | 77 |
| 312 pounds potassium chloride (Kcl) | 21.62 | 17.15 | 7416 | 76 |
| 245 pounds sodium chloride (Nacl) | 21.05 | 17.03 | 7170 | 74 |
| 226 pounds ammonium chloride ($NH_4cl$) | 21.80 | 16.47 | 7181 | 73 |
| 279 pounds ammonium sulfate ($NH_4)_2SO_4$) | 21.45 | 16.48 | 7070 | 78 |
| 156 pounds potassium chloride and 122 pounds sodium chloride | 21.04 | 17.25 | 7259 | 73 |
| Check—no treatment | 21.58 | 17.13 | 7393 | 78 |
| Machine check—drill run empty over plot | 20.69 | 17.05 | 7055 | 71 |
| General mean | 21.29 | 17.02 | 7243 | 75 |
| CV (percent) | 6.23 | 2.15 | 6.58 | -- |
| LSD 5 percent point | NS | .43 | NS | |
| LSD 1 percent point | NS | .57 | NS | |

**Table 3.**—Summarized results, salt study, Bridger, Montana, 1947.

| Treatment description and rates per acre | Roots per acre (tons) | Sugar content (percent) | Gross sugar per acre (pounds) | Beets per 100 feet (number) |
|---|---|---|---|---|
| 300 pounds sodium sulfate ($Na_2SO_4$) | 16.27 | 18.15 | 5906 | 96 |
| 367 pounds potassium sulfate ($K_2SO_4$) | 17.20 | 18.10 | 6226 | 96 |
| 312 pounds potassium chloride (Kcl) | 16.06 | 18.28 | 5872 | 94 |
| 245 pounds sodium chloride (Nacl) | 16.78 | 17.98 | 6034 | 93 |
| 226 pounds ammonium chloride ($NH_4cl$) | 17.28 | 17.53 | 6058 | 93 |
| 279 pounds ammonium sulfate ($NH_4)_2SO_4$) | 16.04 | 17.61 | 5649 | 89 |
| 156 pounds potassium chloride and 122 pounds sodium chloride | 15.96 | 18.45 | 5889 | 89 |
| Check—no treatment | 15.90 | 18.00 | 5724 | 92 |
| Machine check—drill run empty over plot | 16.21 | 18.05 | 5852 | 92 |
| General mean | 16.41 | 18.02 | 5912 | 93 |
| CV (percent) | 6.91 | 1.93 | 7.17 | -- |
| LSD 5 percent point | NS | .41 | NS | |
| LSD 1 percent point | NS | .54 | NS | |

At Laurel, Montana, (table 1) the differences existing in yield of beets did not reach the 5 percent level of significance. Similarly the other two tests gave no significant response in yield to any of the treatments. At all three locations the lowest sugar content is associated with applications of nitrogen. These differences surpassed the 5 percent level of significance at Powell, Wyoming, and Bridger, Montana, (tables 2 and 3).

The average differential in yield obtained from different salts in the three tests as compared to the check is given in table 4. In this analysis the results of certain treatments were combined. The machine check and the one treatment which included both potassium and sodium chloride were omitted.

**Table 4.**—Three tests average increase or decrease over check for various salts.

| Classification | Increase or decrease over check | | |
|---|---|---|---|
| | Yield per acre (tons) | Sugar content (percent) | Gross sugar per acre (pounds) |
| Sulfate salts | +.13 | —.05 | + 32 |
| Chloride salts | +.48 | —.01 | +111 |
| Sodium salts | +.18 | +.20 | +141 |
| Potassium salts | +.42 | +.23 | +231 |
| Ammonium salts | +.33 | —.52 | —156 |

Again in table 4 the reduction in sugar percentages caused by the application of ammonium salts is apparent. If one were to comment further on table 4, it seems that the chloride salts caused more favorable response in yield than did the sulfate salts. However, further study of tables 1, 2, and 3 shows that this apparent difference exists only in a comparison of the ammonium chloride with the ammonium sulfate. It may be observed that the ammonium chloride treatment yielded more than the ammonium sulfate in each of the three tests with no reversals in yield performance appearing. Combining this observation with a very definite visual difference in top growth resulting from the ammonium chloride treatment over that resulting from the ammonium sulfate treatment, it would seem unjust to discount completely this trend. Both ammonium salts produced larger tops than the check. Such a response in top growth was not evident from any of the other treatments. The rather late date of application of the fertilizers may have attributed to the low response in yield.

## Summary

In comparisons of chloride and sulfate salts of sodium, potassium, and ammonium as fertilizers for sugar beets, greater top growth was apparent from the ammonium chloride treatment as compared with the ammonium sulfate treatment. Both treatments produced larger tops than did the check. A comparison of root yields revealed no conclusive differences between any of the treated plots or the check. A reduction in percentage of sugar resulted from the use of ammonium salts. This difference was highly significant for two of the three tests.

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# Sugar Beet Fertilizer Experiments on Recently Leveled Land[1]

ROBERT S. WHITNEY, D. W. ROBERTSON and ROBERT GARDNER[2]

IN ORDER to facilitate the uniform application of irrigation water, a portion of the Agronomy farm at Fort Collins, Colorado, was leveled in the spring of 1946. The land surface was graded to an exactly uniform slope of ½ percent at right angles to the farm ditch. The cut necessary to accomplish the leveling varied from 2 to 28 inches. Over most of the land, the surface soil was completely removed exposing light colored subsoil layers which were high in lime and had a very coarse columnar structure. This land was divided into five series with five plots in each series to test the effect of barnyard manure and commercial fertilizers on the yield of crops grown in a normal 8-year rotation (corn, sugar beets, wheat, sugar beets, alfalfa with barley companion crop, 3 years of alfalfa). A latin square design was used in the experiment. The second year of the test was completed in 1947.

The fertilizer treatments for both years are given in table 1. The commercial fertilizer combinations were applied at a rate equal to one-half of the amounts of total nitrogen (N), phosphorus ($P_2O_5$), and potassium ($K_2O$) contained in the manure. With the exception of the check plot, all plots had received the same total amounts of N, N and P, and N, P, and K, as the case may be by the beginning of the second year of the experiment.

Table 1. Fertilizer treatments.

| Treatments | Analysis | Rate per acre Spring, 1946 | Rate per acre Fall, 1946 |
|---|---|---|---|
| I Manure | 0.81% Total N<br>0.41% Total $P_2O_5$<br>0.98% Total $K_2O$ | 26.7 tons | ---------- |
| II Treble superphosphate | 0-43-0 | 262 pounds | 262 pounds |
| III Ammonium nitrate | 32.5-0-0 | 662 pounds | 662 pounds |
| Treble superphosphate | 0-43-0 | 262 pounds | 262 pounds |
| IV Ammonium nitrate | 32.5-0-0 | 662 pounds | 662 pounds |
| Treble superphosphate | 0-43-0 | 262 pounds | 262 pounds |
| Potassium sulfate | 0-0-50 | 523 pounds | 523 pounds |
| V No treatment | ---- | ---------- | ---------- |

## Experimental Results

In preparation for the first crop (corn) the land was spring plowed; it was not possible to prepare a good seedbed due to the cloddy nature of the soil. The manure was turned under and the commercial fertilizer was

[1]The authors are indebted to G. W. Deming, Associate Agronomist, Division of Sugar Plant Investigations, B.P.I., S.A.E., for running the sugar analyses, to the Beet Sugar Development Foundation for financial support, and to the Soil Conservation Service for supervising the land leveling.

[2]Associate Agronomist, and Agronomists, respectively, Colorado Agricultural Experiment Station, Fort Collins, Colo. Authorized by the Director of the Colorado Agricultural Experiment Station for publication as Scientific Journal Series Article No. 270. Received for publication in January 1948.

drilled in with a seed drill having a fertilizer attachment. The plots treated with manure yielded 45.28 bushels of shelled corn per acre, and were the only ones producing a significant increase over the check plots which yielded 15.64 bushels. The commercial fertilizer plots varied in yield from 18 to 23 bushels per acre. The major limiting factors in these tests were a lack of available phosphorus and nitrogen. A deficiency of phosphorus was apparent even on those plots receiving this nutrient.

For the sugar beet crop in the second year, commercial fertilizers were applied in the fall in amounts equal to the applications for the corn crop (table 1) and the entire test area was immediately plowed. In the spring of 1947, the land was worked into a very good seedbed. The limey lumps and clods showed a remarkable mellowing. The plots were seeded to sugar beets on April 3 and harvested about the middle of October. The beets were irrigated July 13, August 12, and September 2, never being allowed to suffer for water.

**Table 2.**—Yields sugar beets 1947.

| Treatments | Tons beets per acre | Pounds sugar per acre | Percent Sugar | Percent Stand | Tons tops per acre | |
|---|---|---|---|---|---|---|
| | | | | | Green | Dry |
| I Manure | 16.64 | 4719 | 14.14 | 98.2 | 10.45 | 1.47 |
| II P | 12.13 | 3444 | 14.23 | 95.6 | 6.84 | 1.05 |
| III N and P | 18.60 | 4793 | 12.85 | 97.6 | 17.47 | 2.12 |
| IV N, P, and K | 19.57 | 4997 | 12.76 | 97.8 | 17.22 | 2.03 |
| V No treatment | 8.17 | 2189 | 13.42 | 77.8 | 8.19 | 1.12 |
| Difference for significance | | | | | | |
| 5 percent point | 1.71 | 697 | 0.80 | 8.91 | 2.16 | 0.29 |
| 1 percent point | 2.40 | 997 | 1.12 | 12.49 | 3.02 | 0.41 |

All treatments resulted in a significant increase in yield of beets and total sugar per acre over the check plot. Greater than a two-fold increase in yield and total sugar per acre was obtained on all plots that received nitrogen in addition to phosphorus (including the residual manure plots). The effectiveness of the treatments was obvious throughout the growing period (figure 1).

The percentage sugar in all treatments was low. Phosphorus alone gave a slight increase in sugar percentage over the check plot while those plots treated with ammonium nitrate were more than 1 percent lower than either the manure or phosphate plots. Of interest was the fact that in these trials the beets receiving nitrogen did not vary significantly in percentage sugar from the beets on the no treatment plot.

The death of young beets on the "no treatment" plots resulted in a real depression in percentage of stand on these plots. The yield of tops, as was expected, was increased by the nitrogen fertilizers.

While the fertilizer application in each case was rather high, all treatments resulted in a monetary profit if compared with the check plot even when all the fertilizer applied in both years of the test was charged to the one beet crop.

Figure 1—Views of the plots treated with ammonium nitrate and treblesuperphosphate (left) and the check plot (right).

←23 June, 1947

19 July, 1947→

←10 September, 1947

## Discussion

The experiment demonstrated that the main limiting factors for the production of sugar beets on this recently leveled land were the nitrogen and phosphorus supply. This was previously demonstrated for a number of Colorado subsoils (1)[3] under greenhouse conditions. No response to potassium was apparent.

Both manure and commercial fertilizers were effective in producing normal yields of beets. The yields from the plots treated with commercial nitrogen and phosphorus were somewhat better than the yields from the manured plots, but this might be expected since only the residual effect of the manure (applied in the spring of 1946) was involved. For sugar beets on normal land, Gardner and Robertson (2) demonstrated the comparable efficacy of manure, and commercial nitrogen plus phosphorus when the latter were applied at a rate equal to the amounts of these elements contained in the soluble portion of manure. Manure and manure plus phosphate fertilizer applied to leveled land were previously shown to be effective in increasing the yields of spring barley (3). The fact that manure and commercial fertilizers failed to produce equivalent results on corn the first year of the test was probably due to a lack of phosphorus. Insufficient phosphorus may have been related to improper placement, insufficient amounts, or too late an application of phosphate fertilizer. This matter is receiving further study.

## Summary

1. Sub-soil exposed by recent leveling operation was shown to be seriously deficient in nitrogen and phosphorus.

2. Manure plowed under gave significant increases in yields of corn and sugar beets. Commercial fertilizer drilled in before planting did not increase the yield of corn, but when additional fertilizer was plowed in at the time of fall preparation of the land for the second crop, yields of sugar beets twice as high as those from the "no treatment" plots were obtained.

3. The stand of sugar beets on those plots receiving no fertilizer was significantly lower than the treated plots.

4. Even at the high rate of fertilizer application used, all treatments resulted in a net profit.

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# Simulated Hail Damage to Sugar Beets[1]

H. E. Morris

Hail is a major hazard of many crops grown east of the Continental Divide in Montana. Methods have been developed to estimate accurately the hail damage on cereal crops, but these methods are not adapted to some other crops, such as sugar beets, beans, potatoes, peas, etc.

In recent years damage from hail has occurred annually on a rather large acreage of sugar beets and the need of information for properly calculating hail damage is apparent.

A preliminary experiment was conducted in 1946 at the Huntley Branch Station, Huntley, Montana, in which the effect of simulated hail damage on sugar beets was studied. The work was planned to study the effect of seasonal occurrence and intensity of hail damage on the ability of beets to recover and on the subsequent yields.

A one-fourth acre plot (272.3 feet long and 40 feet wide) subdivided into 24 small plots was used.

The ground was fall plowed and received the recommended cultural practices in the spring and summer similar to those used on the other beet acreage on the station. Segmented seed of U.S. 22 was used. The beets were planted April 12 at the rate of 4 pounds of seed per acre. The beets were harvested September 26, 1946 (166 days after planting).

Simulated hail damage was produced three times during the summer at approximately monthly intervals beginning June 26. On each date 100, 50, 25, and 0 percent of the leaf area of the beet plants were destroyed on each of two small duplicate plots (a plot consisted of two rows of beets 26.2 feet long). The leaf area was destroyed by whipping the plants with a flexible wooden stick. (During the growing season of 1946 two hail storms occurred, the first on June 24 causing about 10 percent damage, and the second on July 21, causing 40 percent damage to the beet foliage). The results of this experiment are presented in table 1 as an average of the duplicate plots. The greatest reduction in yield occurred where all the leaves were destroyed on June 26. The average yield of these plots was 8.96 tons per acre, while the undamaged plots yielded 15.53 tons.

There was practically no difference in the plots where the foliage was damaged 50 and 25 percent, respectively, on June 26. They yielded approximately 13 tons and the check 15.5 tons.

When the defoliation was made on July 21, the plots with 100 percent of damage yielded 11 tons, and the 50 and 25 percent plots yielded 13 and 15 tons, respectively, in comparison to the check which yielded 17 tons.

[1]Contribution from Montana State College, Botany and Bacteriology Department, Agricultural Experiment Station. Paper No. 194, Journal Series.

**Table 1.—Simulated hail injury to sugar beets 1946. Huntley Field Station F-O-III-3.**

| No. of plot | Foliage injury | Yield tons | Tops percent | Roots percent | Beet average weight pounds | Sugar percent |
|---|---|---|---|---|---|---|
| | | Defoliated June 26, 1946 | | | | |
| 1 | 100 | 8.96 | 46 | 54 | 0.98 | 15.5 |
| 2 | 50 | 13.57 | 39 | 61 | 1.12 | 16.1 |
| 3 | 25 | 12.97 | 37 | 63 | 1.35 | 16.1 |
| 4 | 0 | 15.53 | 39 | 62 | 1.52 | 15.0 |
| | | Defoliated July 21, 1946 | | | | |
| 5 | 100 | 10.98 | 44 | 56 | 1.14 | 14.6 |
| 6 | 50 | 12.95 | 35 | 65 | 1.20 | 16.0 |
| 7 | 25 | 15.07 | 35 | 65 | 1.23 | 16.0 |
| 8 | 0 | 17.19 | 40 | 60 | 1.25 | 16.2 |
| | | Defoliated August 21, 1946 | | | | |
| 9 | 100 | 11.63 | 32 | 68 | 1.10 | 15.3 |
| 10 | 50 | 13.04 | 32 | 68 | 1.28 | 15.9 |
| 11 | 25 | 13.88 | 33 | 69 | 1.26 | 16.6 |
| 12 | 0 | 16.82 | 37 | 63 | 1.30 | 16.0 |

When the defoliation was made on August 21, the plots with 100 percent of damage yielded 12 tons, and the 50 and 25 percent plots yielded 13 and 14 tons, respectively, in comparison to the check which yielded 17 tons.

The experiment was somewhat modified and repeated in 1947. A field consisting of $1\frac{1}{8}$ acres (field 272.3 feet long by 178 feet wide) was used. One half of the field was fertilized in the fall of 1946 with 16 tons of manure and 200 pounds of treble superphosphate on an acre basis. The other half was not fertilized. The field was fall-plowed and in the spring and summer received the recommended cultural practices, similar to those used on the other beet acreage on the station.

Segmented seed of U.S. 22 was planted on May 6, and the beets were harvested on September 26, 1947 (142 days after planting). One series of subplots in each of the fertilized and unfertilized parts of this field received an application of N (150 pounds of ammonium sulphate and 150 pounds of sodium nitrate on an acre basis) after the beets were injured. The beet foliage was destroyed 100, 50, 25, and 0 percent on each small plot, consisting of two rows of beets 26.2 feet long, on June 26, July 26, and August 28, 1947.

Detailed data are presented in table 3 for the half of the field which was fertilized in the fall of 1946.

The results indicate that 100 percent damage to foliage on June 26 and July 26, on plots where nitrogen was added, resulted in a 6-ton decrease in yield, while with a 50 or 25 percent damage the loss was from 2 to 4 tons. The damage to foliage on August 28 caused a reduction in the sugar content of beets of 2 to 3 percent. Due to unfavorable conditions at harvest yield data were not obtained on these plots.

Table 2.—Simulated hail injury to sugar beets 1947.
Huntley Field Station F-O-II-1, 2
Fertilized Land[1]

| Plot No. | N[2] added after injury: Percent injury | Yield tons | Tops percent | Root percent | Sugar Sample: Beet average weight pounds | Sugar Sample: Sugar percent | No N added after injury: Plot No. | Yield tons | Tops percent | Root percent | Sugar Sample: Beet average weight pounds | Sugar Sample: Sugar percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Defoliated 6-26-47 | | | | | | | |
| 1 | 100 | 13.9 | 45 | 55 | 1.05 | 17.1 | 1A | 13.4 | 46 | 54 | 1.07 | 17.0 |
| 2 | 50 | 16.4 | 42 | 58 | 1.36 | 17.3 | 2A | 18.4 | 46 | 54 | 1.47 | 17.0 |
| 3 | 25 | 17.5 | 43 | 57 | 1.42 | 17.1 | 3A | 17.8 | 48 | 52 | 1.59 | 16.5 |
| 4 | 0 | 19.0 | 42 | 58 | 1.38 | 17.2 | 4A | 20.8 | 47 | 53 | 1.59 | 16.7 |
| | | | | | Defoliated 7-26-47 | | | | | | | |
| 5 | 100 | 14.1 | 41 | 59 | 1.04 | 17.2 | 5A | 12.1 | 40 | 60 | 1.20 | 15.6 |
| 6 | 50 | 16.9 | 43 | 57 | 1.45 | 16.4 | 6A | 17.8 | 43 | 57 | 1.49 | 14.9 |
| 7 | 25 | 18.9 | 44 | 56 | 1.41 | 16.3 | 7A | 18.3 | 45 | 55 | 1.69 | 16.4 |
| 8 | 0 | 20.6 | 41 | 59 | 1.95 | 17.2 | 8A | 22.3 | 45 | 55 | 1.46 | 16.6 |
| | | | | | Defoliated 8-28-47 | | | | | | | |
| 9 | 100 | | | | | 14.0 | 9A | | | | | 13.6 |
| 10 | 50 | | | | | 15.4 | 10A | | | | | 16.0 |
| 11 | 25 | | | | | 15.0 | 11A | | | | | 16.4 |
| 12 | 0 | | | | | 16.7 | 12A | | | | | 16.9 |

[1]16 tons manure and 200 pounds T. S. P. per acre.
[2]150 pounds ammonium sulphate plus 150 pounds sodium nitrate per acre.

**Table 3.**—Simulated hail injury to sugar beets 1947.
Huntley Field Station F-O-II-3, 4
Unfertilized Land

| N added after injury | | | | | | | No N added after injury | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Sugar Sample | | | | | | Sugar Sample | |
| Plot No. | Percent injury | Yield tons | Tops percent | Root percent | Beet average weight pounds | Sugar percent | Plot No. | Yield tons | Tops percent | Root percent | Beet average weight pounds | Sugar percent |
| | | | | | Defoliated 6-26-47 | | | | | | | |
| 1 | 100 | 12.9 | 50 | 50 | 1.29 | 17.1 | 1A | 13.0 | 44 | 56 | 1.43 | 17.1 |
| 2 | 50 | 15.9 | 46 | 54 | 1.47 | 17.5 | 2A | 17.3 | 43 | 57 | 1.69 | 16.4 |
| 3 | 25 | 16.9 | 45 | 55 | 1.72 | 17.4 | 3A | 18.5 | 43 | 57 | 1.78 | 16.9 |
| 4 | 0 | 16.8 | 45 | 55 | 2.15 | 16.0 | 4A | 18.6 | 45 | 55 | 1.77 | 17.1 |
| | | | | | Defoliated 7-26-47 | | | | | | | |
| 5 | 100 | 12.8 | 40 | 60 | 1.06 | 16.4 | 5A | 11.5 | 34 | 66 | 1.10 | 16.9 |
| 6 | 50 | 16.0 | 41 | 59 | 1.25 | 17.3 | 6A | 16.5 | 38 | 62 | 1.16 | 17.2 |
| 7 | 25 | 17.1 | 42 | 58 | 1.59 | 17.3 | 7A | 19.5 | 37 | 63 | 1.22 | 17.2 |
| 8 | 0 | 17.9 | 38 | 62 | 1.41 | 17.5 | 8A | 20.5 | 35 | 65 | 1.34 | 17.1 |
| | | | | | Defoliated 8-28-47 | | | | | | | |
| 9 | 100 | | | | | 13.7 | 9A | | | | | 14.1 |
| 10 | 50 | | | | | 15.3 | 10A | | | | | 16.1 |
| 11 | 25 | | | | | 16.1 | 11A | | | | | 17.0 |
| 12 | 0 | | | | | 15.6 | 12A | | | | | 17.9 |

On the plots where no nitrogen was added (table 2) 100 percent damage to foliage on June 26 and July 26 resulted in 7 and 10 tons decrease in yield of sugar beets, respectively, while with 50 and 25 percent of damage the loss was from 2 to 4 tons. The damage to foliage on August 28 caused about the same effect on the sugar content as where nitrogen was applied. Yield records were not obtained on these plots.

The nitrogen application after injury apparently was not beneficial to sugar beets in the fertilized part of this experiment.

Detailed data are presented in table 3 for the half of the field which was not fertilized in the fall of 1946.

On the plots where nitrogen was added following foliage injury on June 26 and July 26, 100 percent damage caused a decrease in yield of 4 and 5 tons per acre, respectively; 50 percent damage, a decrease of 0.9 and 1.9 tons; 25 percent damage, a decrease of 0.0 and 0.9 tons. The greatest reduction in percentage of sugar was shown by the beets on which 100 percent of damage was made on August 28.

On the plots where no nitrogen was added following injury on June 26 and July 26, 100 percent damage caused a decrease in yield of 5.6 and 9.0 tons per acre, respectively; 50 percent damage, a decrease of 1.3 and 4.0 tons; 25 percent damage, 0.0 and 0.9 tons.

A reduction in percentage of sugar occurred in these plots similar to that reported for beets grown on the unfertilized plots where nitrogen was applied after the injury. Due to unfavorable conditions at harvest, yield data for the plots injured on August 28 were not obtained, although the plots were sampled for sugar determination.

There was only a slight difference in the yield, stand, sugar content, etc., between the fertilized plots, the unfertilized plots, and the plots which received an application of nitrogen after foliage injury. The high fertility of the entire experimental plot indicates a sufficient amount of nutrients for practically a 20-ton yield of sugar beets. The nitrogen content of the experimental plots was relatively high in 1947.

The results of 2 years' work show a similarity in certain trends, but more data are necessary before definite conclusions can be drawn.

# Irrigation and Soil Fertility

# Plant Analysis as a Guide to the Nutrition of Sugar Beets in California[1]

ALBERT ULRICH[2]

PROGRESS in the development of plant analysis as a guide to the fertilization of sugar beets rests primarily upon improvements in technique and upon the philosophy associated with the interpretation of the results. Without a satisfactory technique the analytical results are worthless, and even when the analytical values are estimated accurately, they have little meaning unless they can be interpreted in terms of the nutrient status of the crop. It is with these purposes in view that much of the research in plant analysis has been directed.

The early investigations in the use of plant analysis as a guide to the fertilization of sugar beets were based upon sampling procedures and analytical methods developed primarily for other crops (Chapman (2)[3], 1935, Emmert (4), 1934, Thornton (13), 1932, (14) 1933). These methods, with modifications were applied with success by Gardner and Robertson (6), 1935, in Colorado to sugar beet petioles collected from mature leaves of beets in a fertilizer experiment conducted in small plots designed to test the effectiveness of nitrogen, phosphorus and manure on beet growth. They concluded that the petiole test was sufficiently accurate to be applicable to determining the nitrate, phosphate and potassium needs of the soil. With this incentive as a background many experiments have been conducted in our laboratories to improve the methods of analysis, to ascertain the part of the beet leaf (petiole or blade) suitable for analysis, to establish the position on the plant from which to take the sample, to determine the time and frequency of collecting the leaf samples and finally to select the form of each element for analysis which reflects accurately the nutrient status of the beet plant. In other laboratories Brown (1), 1943, concurred with our findings regarding the type of petiole suitable for sampling, while the number of petioles recommended by him for a sample was considerably higher than used in our investigations.

While progress in the experimental technique for applying plant analysis to the solution of nutritional problems with sugar beets has been considerable, developments in the interpretation of the results are not easy to evaluate. A number of workers studying primarily crops other than sugar beets, have presented several interesting viewpoints. Some of these ideas have been mentioned briefly in a review that has appeared recently (Goodall and Gregory (7), 1947, while contrasting theories have been given in

[1]The experiments of the nitrogen series reported in this paper are part of a study being conducted in cooperation with The Spreckels Sugar Company and the International Minerals and Chemical Corporation. Grants-in-aid were received from The International Minerals and Chemical Corporation for the chemical analyses of the petioles from the nitrogen experiments.

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[3]Numbers in parentheses refer to literature cited.

articles by Thomas (12), 1937, Macy (9), 1936, Lundegardh (8), 1941, Clements and Kubota (3), 1943, Ulrich (15), 1943, and in press 1948) and Shear, Crane and Myers (10), 1946.

Of the many concepts of plant analysis which have appeared from time to time, the one centering about the ideas associated with "limiting factors" appears from many aspects to be the most fruitful. This concept in the main, states that increases in yield or growth are obtained from the addition of the factor that is limiting growth. Strict adherence to this theory is not possible because we know that the severity of some of the deficiencies may be modified by accompanying factors. Thus the addition of sodium to a nutrient medium deficient in potassium will enhance the growth of beets initially devoid of sodium. However, sodium in itself will on the average substitute for only a part of the potassium, and thereafter, potassium additions are necessary for more growth. Similar modifications of growth most likely occur for other nutrients, but essentially, the major increases in growth take place only after the addition of the factor that is deficient. This modified theory of "limiting factors" also applies when two or more deficiencies occur at the same time. When this happens major increases in growth take place only by correcting both deficiencies simultaneously, and thereafter, further additions of the factor or factors have no large effect upon the growth of the crop.

## Theoretical Considerations

*Plant Nutrient Equation.*—The nutrient concentration found within the plant or in any one of its parts is an integrated value of all the factors that have influenced the nutrient concentration of the plant up to the time of taking the sample. These factors may be listed as follows: soil (S), climate (CL), time (T), plant (P), management (M) and possibly others. Their relationship to the nutrient concentration (X) of the plant may be readily visualized in the following generalized equation:

$$X = f(S, P, CL, T, M.....)$$

From an inspection of the equation one can readily see that the nutrient concentration of the soil is just one of the many factors that influences the nutrient concentration of the plant. Not only must the concentration of nutrients in the soil be evaluated carefully before an estimate of its supplying power for nutrients can be made correctly, but other soil factors such as its depth, texture, organic matter, pH, aeration, drainage, etc, should be considered in terms of fertility at the same time. In this evaluation of the nutrient concentration of the soil it is obvious that shallow soils must have higher nutrient concentrations than deep soils in order to support plants of comparable yields. An important factor, too, is the plant itself, particularly the quality and extent of the root system. Plants with roots of high foraging capacity will obtain more nutrients from a given soil than from one with a restricted root system of low activity. Likewise plants which are in a favorable climate will require more nutrients than one growing in an

unfavorable environment. Soils with low nutrient concentrations would supply an adequate quantity of nutrients when the demand for nutrients was low during poor growing conditions, but would fail to do so under conditions of good growth. Complicated as these relationships are, they become still more so when the grower introduces his cultural practices on the field when plowing, cultivating, irrigating, liming, cover cropping and fertilizing. Thus, it is no wonder that a simple estimation of the nutrient concentration of the soil often fails to evaluate the fertilizer requirements of a soil correctly. In contrast to *soil analysis*, the analysis of *plants* gives an integrated value of the effects all factors have had upon the nutrient concentration of the plant up to the time of taking the samples. All that remains to be done from the practical point of view is to find a way to interpret the results of the plant analyses so that the necessary changes in the nutritional program for the crop can be introduced effectively during the current growing season or for subsequent crops on the same field.

*Essential Elements.*—Before attempting to interpret the results of plant analysis it is well to pause briefly to reflect upon the relationship of the nutrient elements to plant growth. Through numerous experiments plant physiologists over a period of years have established that certain elements are essential for growth. Without these elements growth decreases and finally fails completely during the vegetative or reproductive cycle of the plant. When an element has been found to be essential for growth, it must be contained within the plant itself, otherwise the element would not be essential. The exact concentration of the element required for growth will depend upon its function in the physical and chemical processes of the plant. Whether this concentration fluctuates within narrow or wide limits will again depend upon its function. Until the function of each element is clearly known, the practicality of plant analysis must be ascertained empirically through the comparison of nutrient concentrations of plants restricted in growth to those not so restricted in growth by a given nutrient. By such comparisons or correlation studies the "critical nutrient" levels for each element and for each crop can be established.

*The Critical Nutrient Level.*—For a given nutrient the critical nutrient level may be defined as that range of concentrations at which the growth of the plant is restricted in comparison to those plants at a higher nutrient level. Whether the critical level is a relatively narrow range of values or fluctuates widely is still a subject of investigation both under greenhouse and field conditions. Thus far, the evidence indicates that for sugar beets the critical levels for nitrogen, phosphorus and potassium fluctuate over a relatively narrow range of values in comparison to the nutrient concentrations that have been observed for beets above the critical level. While preliminary data obtained in the field support these observations, much more evidence is needed over a period of years before the critical nutrient levels for sugar beets grown in the field can be estimated correctly.

*Probability of Response.*—When plants are grown under field conditions the likelihood of getting a growth response from the addition of a

nutrient to the soil will depend upon whether the nutrient concentrations of the plants are above or below the critical level. When the nutrient concentrations of the plants are above the critical level and remain there throughout the entire growth period of the plant, then there is very little chance of getting a response in growth by adding more nutrients. Conversely, when the nutrient concentrations of the plants fall below the critical level, then the chance of getting a growth response under field conditions increases rapidly as the nutrient concentrations in the plants decrease. The magnitude of the response will depend upon the relative abundance of the other growth factors and upon the time and duration of the deficiency. When the relative abundance of the other growth factors is great, then the addition of the deficient nutrient will result in a relatively large increase in yield. However, when another factor or set of factors soon become limiting, then upon the addition of the required nutrient, the yield increases will be relatively small. This small increase in yield will not be detected unless the error of the experiment is very low. Similarly, the chance of getting a measurable growth response in the field will decrease as the duration of the deficiency decreases and the later in the growing season the deficiency first appears.

## Estimation of the Critical Nutrient Level

*Through Pot Experiments.*—A preliminary estimate of the critical nutrient level for a given element and crop may often be obtained by growing plants in pots of soil known to be deficient in a given nutrient. Such an experiment was started on April 29, 1947, with sugar beets of the U. S. No. 15 variety on a soil known to be deficient in phosphorus.[4] When these beets were harvested on September 2, 1947, the recently "matured" leaves were taken from the tops (figure 1), separated into petioles and blades and then dried in a forced-draft oven maintained at 70 degrees C. The dried plant material was ground in a Wiley mill to pass a 40-mesh sieve and analysed for phosphate soluble in 2-percent acetic acid, for potassium (Ulrich (16), 1945) and for nitrate-nitrogen (unpublished procedure). The analytical values are expressed on the dry basis for phosphate in parts per million of phosphorus, nitrate in parts per million of nitrogen and potassium in percentage. The beet yields are for beets topped at the first leaf scar and are given on the fresh basis throughout.

[4]For the experiment 30.0 pounds of uniform soil were placed into 5-gallon pots provided with pans for the return of the drainage water. The soil for the pots was obtained from the vicinity of Paradise, California, and is classified as Aiken clay. This soil is extremely deficient in phosphorus and in order to get beets to grow on it beyond the early two-leaf stage it was necessary to add a small amount of phosphorus to the soil. The amount of treble super-phosphate used in this treatment as well as in the other treatments are given in table 1. On May 24, 1947, when the plants were still in the early two-leaf stage the phosphorus required for each pot was applied between the plants to the bottom of trenches from 1 to 2 inches deep. Nitrogen from ammonium nitrate was applied at the rate of 2.8 grams of N per pot (280 pounds N per acre of surface) on June 3, 1947, and again on July 25, 1947, at the rate of 3.5 grams per pot (350 pounds per acre). When the plants were in the late two-leaf stage they were thinned to four plants to a pot. These plants grew well and continued to do so until those with the low phosphorus applications showed definite signs of reduced growth accompanied by a deep greening of the leaf blades. These were the main signs of stress shown by the plants except during the cotyledon stage when phosphorus-deficient plants had a reddish caste and when in the later stages of growth an occasional leaf blade showed some purpling or reddening between the veins or a darkening of the veins. At the time of harvest on September 2, 1947, a few of the plants in about half of the pots with the three highest phosphorus treatments had developed leaf symptoms similar to potassium deficiency, which in a few instances was confirmed by leaf analysis.

Figure 1.—Selection of sugar beet leaves for analysis. A leaf stalk from any one of the recently "matured" fully expanded leaves marked "A" in the photograph may be included in the plant sample. Avoid the small leaves in the center or the old leaves of the outer whorls of the plant.

Of major interest from the standpoint of plant analysis are the results illustrated graphically in figures 2 and 3. In figure 2 in which the soluble phosphate-phosphorus values of the leaf petioles are plotted against the corresponding yields, the beet yields increase sharply with the additions of phosphorus to the soil, while at the same time the phosphorus concentrations in the petioles fail to increase. In this portion of the curve the yields increase directly in relation to the quantity of phosphorus the plants can obtain from the soil. Then as more phosphorus is added to the soil the yields and phosphorus concentrations within the petioles increase simultaneously until the critical level of 600-800 parts per million is attained. Thereafter the soluble phosphate-phosphorus concentrations increase in the petioles of the beets without a corresponding increase in yield. In figure 3, in which the soluble phosphate-phosphorus concentrations of the leaf blades are compared with the yields, the results are much the same as in figure 2, except that here the zone in which the yields and phosphorus concentrations increase simultaneously is much broader than when the petioles are analysed (figure 2). Accordingly, from the diagnostic point of view the petioles would serve

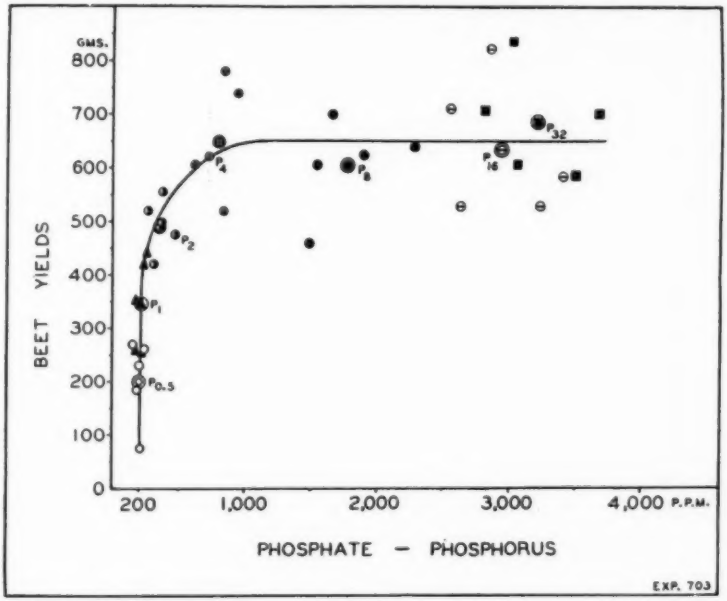


Figure 2.—Relationship of beet root yields (fresh basis) to the concentration of phosphate phosphorus (dry basis) in *petioles* of recently "matured" leaves. $P_1$=1.00 grams $P_2O_5$ (2.27 grams treble superphosphate) per pot or 100 pounds $P_2O_5$ per acre. The points which are circled represent average values for a treatment.

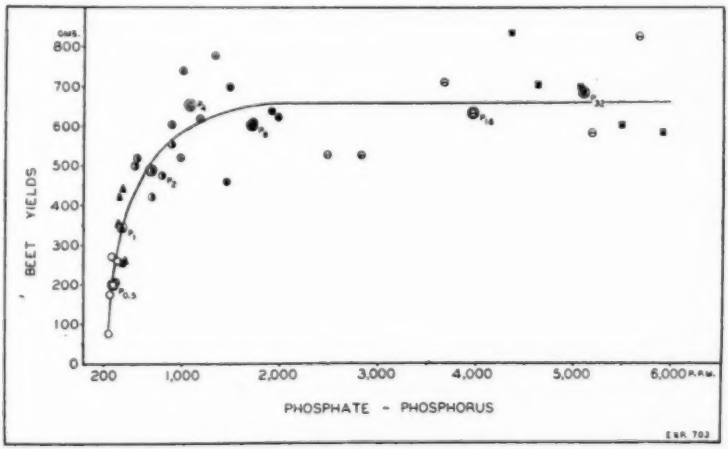


Figure 3.—Relationship of beet root yields (fresh basis) to the concentration of phosphate phosphorus (dry basis) in *blades* of recently "matured" leaves. $P_1$=1.00 grams $P_2O_5$ (2.27 grams treble superphosphate) per pot of 100 pounds $P_2O_5$ per acre. The points which are circled represent average values for a treatment.

better than the corresponding blades as a means of estimating the phosphorus status of sugar beets.

A review of the yields, sugar percentages and chemical analyses of the leaves presented in table 1 discloses several points of interest. When phosphorus was added to the soil in increasing amounts the yields of tops and of beets increased rapidly at first and then more slowly with further additions of phosphorus until the increases in yield were not significant statistically. In the meantime the soluble phosphate-phosphorus concentrations of the petioles and blades, as mentioned earlier, increased very slowly at first and then very rapidly. Of the two plant parts analysed for phosphorus the blades attained higher soluble phosphate-phosphorus concentrations than the petioles. The potassium concentrations of the petioles and blades, in contrast to the phosphorus concentrations, were the highest in the low phosphate plants and then gradually decreased as phosphorus was applied to the soil. Of the plant parts studied, the potassium concentrations of the petioles were higher than the blades for the lowest phosphorus treatment, and then thereafter, the potassium concentrations in the petioles decreased more rapidly than the blades as phosphorus was applied to the soil. That these low potassium values were on the verge of becoming critical was suggested by the fact that a few plants of the three highest phosphorus treatments had a few leaves which showed leaf scorch similar to the symptoms of potassium deficiency. These leaves upon analysis were found to have potassium concentrations comparable to those of plants known to be deficient in potassium. Thus, in future pot experiments with sugar beets on this soil, potassium as well as nitrogen, should be included as a basic treatment. The nitrate-nitrogen concentrations in the petioles decreased only with the high phosphorus applications, but even here the nitrogen supply was ample for growth at harvest time. Another point of considerable interest is the fact that the sugar concentrations of the beets failed to change significantly even though large changes took place in the beet yields and in the phosphorus and potassium concentrations of the leaves of the plants.

**Table 1.**—Summary of results for sugar beets grown in pots of Aiken clay fertilized with increasing amounts of phosphorus.

| Treatments[3] | Weight of tops | | Sugar[1] (Roots) | Weight of beets[1] | Soluble phosphate phosphorus[2] | | Potassium[2] | | Nitrate-nitrogen[2] |
|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Dry | | | Petioles | Blades | Petioles | Blades | Petioles |
| | gms. | gms. | % | gms. | ppm. | ppm. | % | % | ppm. |
| $P_{0.5}$ | 256 | 60 | 13.1 | 202 | 201 | 289 | 3.42 | 3.17 | 3540 |
| $P_1$ | 454 | 89 | 13.0 | 346 | 210 | 378 | 2.35 | 3.22 | 3890 |
| $P_2$ | 765 | 124 | 13.6 | 493 | 355 | 680 | 1.31 | 2.43 | 4680 |
| $P_4$ | 892 | 136 | 13.3 | 653 | 786 | 1070 | 1.25 | 2.19 | 3160 |
| $P_8$ | 953 | 148 | 14.0 | 607 | 1768 | 1700 | 1.09 | 1.98 | 1750 |
| $P_{16}$ | 1026 | 154 | 14.0 | 637 | 2932 | 3956 | 1.08 | 1.98 | 1940 |
| $P_{32}$ | 1011 | 154 | 13.5 | 686 | 3214 | 5078 | 1.15 | 1.85 | 2120 |
| Significant difference[4] | 145 | 17 | N.S. | 115 | 275 | 790 | 0.39 | 0.46 | 1280 |
| F-value[5] | 36.3 | 40.7 | 1.68 | 21.5 | 190 | 48.4 | 43.7 | 13.7 | 6.43 |

[1]Fresh basis.
[2]Dry basis.
[3]$P_1$=1.00 grams $P_2O_5$ (2.27 grams treble superphosphate) per pot or 100 pounds $P_2O_5$ per acre. Each treatment was replicated five times.
[4]Significant differences are for the 5 percent level. N.S.=not significant.
[5]The F-values required for significance at the 5 percent and 1 percent levels are 2.51 and 3.67, respectively (Snedecor (11), 1946).

*Under Field Conditions.*—The estimation of the critical nutrient level for sugar beets under field conditions is considerably more difficult than when plants are grown in pots of soil. In the field it is frequently impossible to control the conditions of the experiment as rigidly as desired, and it is often impossible to locate the experiments on soils with fertility levels as low as those which can be induced in pot experiments. But in spite of these difficulties data often can be obtained which will assist in getting an estimate of the critical nutrient level for sugar beets growing in the field. This estimate of the critical nutrient level may be established in the field in much the same manner as in the pot experiments just reviewed for phosphorus. Success by this procedure, just as in the pot experiments, will depend upon getting large differences in beet growth and in harvesting the beets before the nutrient supplies have been depleted within the leaves to the same low level for all rates of the fertilizer application. Often this will require harvesting the beets in mid-season in order to get large differences in yield that can be compared to large differences in nutrient concentration of the beet leaves. By following this procedure it is believed that the critical nutrient level for beets can be established rather efficiently under field conditions.

Another approach to estimating the nutrient level at which the growth of a crop is reduced, is through the collection of leaf samples at frequent intervals during its growing season. When the nutrient under study becomes deficient in the untreated plants and decreases within the plant to a relatively constant level, this may be taken as being at or below the critical level for that nutrient. Through many experiments of this nature, conclusions may be drawn as to the probable nutrient level at which the growth of the crop is reduced significantly below those at higher nutrient levels.

An example of the latter procedure was made available through a cooperative field experiment conducted with the International Minerals and Chemical Corporation and The Spreckels Sugar Company. In this experiment the effect of nitrogen on the growth of the beets was primarily under investigation while phosphorus was applied only in combination with the highest nitrogen application. Leaf samples were collected at about 14-day intervals starting at the time of applying the fertilizer on April 26 (first irrigated thereafter on May 1) and ending with the harvest of the beets on August 21, 1947. Other details of the experiment may be stated briefly as follows:

Sugar beet seed of the variety U. S. 15G was planted on January 26, 1947, in rows spaced 16 inches on a ridge and 24 inches between ridges. The beets were thinned on March 22 and then fertilized on April 25 by means of a Fairbank (5), 1940, two-row fertilizer applicator. The fertilizer

was applied at the side of the beets in the wide spacing (irrigation furrow) at a depth of 4½ inches and a distance of 4 inches from the beets. Each plot was 6 rows wide and 100 feet long, and only the center 80 feet of the 2 center rows were harvested for yields and sugar determinations. The treatments applied were untreated, 80N, 160N, 240N and 240N+200 $P_2O_5$, where N equals "pounds of nitrogen per acre from ammonium nitrate" and $P_2O_5$ equals "pounds of $P_2O_5$ per acre from treble superphosphate." The five treatments were replicated eight times according to the randomized block technique (Snedecor (11), 1946). Plant samples consisting of 20 petioles each were collected from each plot at 2-week intervals from the time the beets were fertilized until they were harvested on August 21, 1947. The first petiole for the sample was taken from a recently "matured" leaf from a beet in the 2 center rows after walking into the plot 2.5 feet. Thereafter a petiole was taken every 5 feet alternating from row to row until 20 petioles had been collected. The samples were received at Berkeley, California, within 24 to 48 hours after their collection and upon their arrival were cut into sections from 2 to 5 millimeters in length. A 50 or 100-gram sample of each was dried in an oven at 70 degrees C., ground in a Wiley mill to pass a 40-mesh sieve and then analysed for nitrate-nitrogen (unpublished procedure), phosphate-phosphorus and potassium (Ulrich (17), 1945).

The results for the nitrate-nitrogen analyses are presented in figure 4 and in table 2. An inspection of the curves in figure 4 show that there was no significant difference in nitrate concentration of the beets prior to their fertilization. Thereafter the addition of nitrogen to the plots increased the nitrate concentrations of the beets in agreement with the rate of nitrogen applied. The lowest nitrate-nitrogen values were observed for the untreated beets throughout the experiment. These on May 13 had decreased markedly over those for April 25. Another decrease took place by May 26 and thereafter the nitrate values for the untreated beets were more or less constant even through to the time of beet harvest. Accompanying these low nitrate values for the untreated beets there was observed during June a distinct decrease in top growth of the beets in comparison to those beets fertilized with 80 pounds or more of nitrogen. At that time the treatments with more than 80 pounds of nitrogen had no further visible effect on the growth of the beets. Combining these observations, namely the low nitrate values with the poor growth of the untreated beets, along with the fact that only the untreated beets gave lower yields at harvest time than for any of the other treatments (table 2), the critical nitrogen value for beet petioles appears from this experiment to be approximately 400 parts per million of nitrate-nitrogen. How much more or less than 400 parts per million must await the results of experiments now in progress or to further improvements in technique or to a more effective statistical analysis of the results now available.

**Table 2.**—Nitrate-nitrogen of sugar beet petioles as related to yields and percentages of sugar in beets grown in field plots near Woodland, California, on Yolo fine sandy loam.

| Treatment[2] | Nitrate-nitrogen[1] | | | | | | | | | Beet yield | Sugar | Sugar yield |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | April 25 | May 13 | May 26 | June 9 | June 23 | July 8 | July 21 | Aug. 4 | Aug. 18 | | | |
| | ppm. | ppm. | ppm. | ppm. | ppm. | ppm. | ppm. | ppm. | ppm. | Tons/acre | % | Tons/acre |
| Untreated | 9,600 | 2,360 | 920 | 233 | 310 | 412 | 397 | 380 | 407 | 25.09 | 17.47 | 4.38 |
| 80N | 10,300 | 7,760 | 4,670 | 1,420 | 1,360 | 700 | 610 | 560 | 670 | 27.94 | 16.87 | 4.71 |
| 160N | 10,800 | 10,600 | 9,360 | 3,050 | 2,690 | 1,280 | 880 | 740 | 830 | 28.05 | 16.09 | 4.52 |
| 240N | 10,000 | 11,000 | 11,000 | 4,670 | 4,000 | 2,920 | 1,840 | 1,470 | 1,090 | 28.79 | 15.49 | 4.46 |
| 240N+200$P_2O_5$ | 10,400 | 11,700 | 11,100 | 4,630 | 4,230 | 3,390 | 2,110 | 1,390 | 1,240 | 27.75 | 15.42 | 4.28 |
| Significant difference[3] | N.S. | 1,950 | 2,140 | 820 | 790 | 1,160 | 880 | 490 | 470 | 2.09 | 0.54 | N.S. |
| F-value[4] | 0.99 | 32.5 | 36.7 | 48.0 | 37.5 | 11.2 | 11.4 | 8.68 | 4.11 | 3.85 | 89.9 | 2.27 |

[1]Values are expressed on the dry basis.
[2]Arranged in eight randomized blocks. N=pounds of nitrogen from ammonium nitrate. $P_2O_5$=pounds of $P_2O_5$ from treble superphosphate.
[3]Significant differences are for the 5 percent level. N.S.=not significant.
[4]The F-values required for significance at the 5 percent and 1 percent levels are 2.71 and 4.07, respectively (Snedecor (11), 1946).

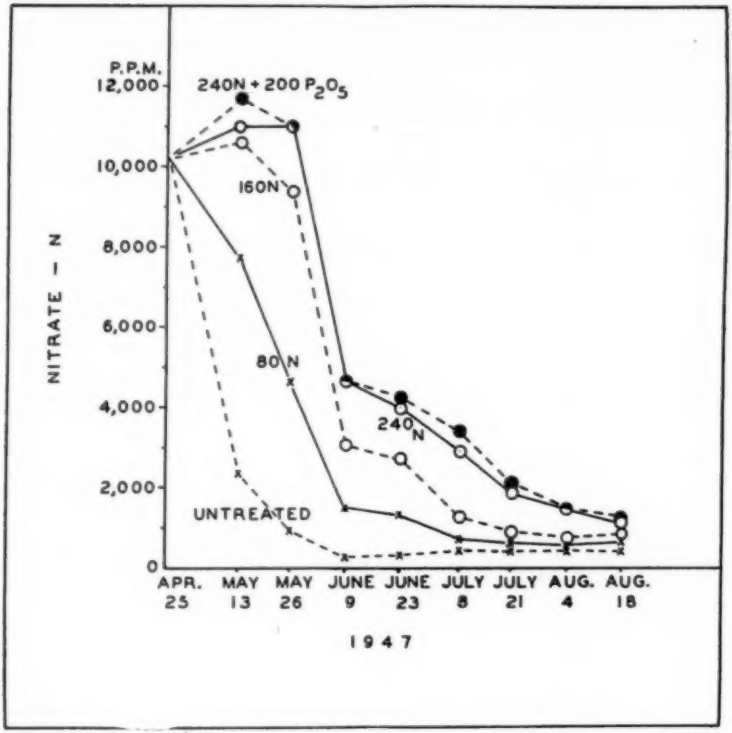


Figure 4.—Nitrate nitrogen (dry basis) of recently "matured" petioles as influenced by the amount of nitrogen applied and the date of leaf sampling. N=pounds per acre of nitrogen from ammonium nitrate and $P_2O_5$=pounds per acre of $P_2O_5$ from treble superphosphate.

## Practical Applications of Plant Analysis

When once the critical nutrient level for an element has been established for a crop through many field experiments, plant analysis may have several interesting applications. Some of these applications include: (1) a determination of the kind of nutrient that might be deficient in the field; (2) estimation of the time of the application and the amount of fertilizer to apply; (3) aid in selecting the location of fertilizer experiments and (4) in the maintenance of soil fertility. Of these applications perhaps the most interesting from the practical standpoint is the use of plant analysis as an aid in the maintenance of soil fertility. Plants may be analysed in a systematic manner such as in the nitrogen experiment just reported (figure 4 and table 2). When the beets reach the critical level relatively early in the growing season as in the case of the untreated beets of the nitrogen experiment (figure 4) then emergency applications of nitrogen may be made to the field of beets. While emergency applications of nitrogen have effectively

increased the yields of beets during the current growing season, nevertheless valuable growing time is often lost from the time the deficiency is detected to the time the nitrogen is absorbed by the plants. For this reason the use of plant analysis for emergency applications of fertilizers should not be stressed, but rather its use in the maintenance of soil fertility. This can be done rather conveniently when once it is recognized that certain fields from their fertilizer history are apt to become deficient in a given nutrient, as for example in the case of the field with the nitrogen experiment (figure 4 and table 2). In succeeding crops of beets on this field, nitrogen may be applied at a pre-determined time and rate before the beets are apt to become deficient in nitrogen. This time of application may be indicated by plant analysis. From figure 2 of the nitrogen experiment, the results for the untreated beets indicate that nitrogen should be applied so as to be available to the beets by the 1st of May. As to the amount of nitrogen to apply to succeeding beet crops, this cannot be estimated from the results of plant analysis for a single year on a given field unless this estimate is based on other data or upon the results of an experiment conducted concurrently using different rates of nitrogen as part of the treatments such as in the nitrogen experiment (figure 4 and table 2). The results of this experiment may be used as an illustration in estimating the amount of nitrogen to apply on subsequent crops of beets on this field. For this discussion let us assume that the critical nitrogen level for sugar beets has been established through many experiments to be approximately 1,000 parts per million of nitrate-nitrogen. Then in the case of the untreated plots, the beets were below the critical level from the latter part of May to the time of their harvest on August 21, 1947. During this 10-week period the results for the untreated beets indicate that they could have used more nitrogen for growth during the growing season, but what is not shown by the petiole analyses of the untreated beets is the degree of nitrogen deficiency. In some fields this deficiency may be extreme, while in others it may be relatively small, depending upon the rate of formation of available nitrogen. In the present experiment it may be surmised from the relatively good yield of 25.09 tons per acre from the untreated plots (table 2) that a considerable amount of nitrate was formed by the soil during the growing season of the beets. That the beets could actually use more nitrogen as indicated by the petiole analyses was shown by the 2.85-ton increase in beet yields obtained for the plots treated with 80 pounds of nitrogen per acre (table 2). Along with the increase in yield there was also an increase in the nitrate concentrations of the petioles (figure 4) so that the beets were below the critical nitrogen level for 7 weeks prior to harvesting them instead of the 10 weeks for the untreated beets. For the 160-pound per acre nitrogen treatment, the beets were below the critical nitrogen level for only 5 weeks before harvest, while for the 240-pound nitrogen application the beets were still *above* the critical nitrogen level when they were harvested. Of the increases in nitrate concentration in the leaf petioles with each increase in nitrogen added only the 80-pound nitrogen application was correlated with a significant increase in

beet yield. The sugar percentages decreased significantly with each increment of nitrogen applied, and the net effect of this decrease in sugar concentration of the beets was a cancellation of the yield increase in the 80-pound nitrogen treatment. All these facts indicate that the beets were harvested prematurely, and what the final outcome would have been had they been left in the field longer should be a subject of considerable interest in future experiments. However, from the practical standpoint the 80-pound nitrogen treatment appears as a good basic nitrogen application for the next crop of beets on this field, providing all other conditions remain quite similar and that the beets could be left in the field longer to utilize completely the nitrogen applied. In any event the validity of the recommendations made with respect to time and to the rate of nitrogen applied should be confirmed through plant analysis for each crop grown on the field.

Aside from learning through plant analysis what fertilizer, and the approximate amount and time to apply it, one may also learn what materials are available to a crop in sufficient amounts for the time being. In the present experiment the phosphate and potassium concentrations[5] of the petioles, except for phosphorus on April 26, were well above what we now consider to be their critical concentrations, and accordingly their omission in fertilizer treatments for the next crop of beets would be well justified. The correctness of this assumption, however, should again be confirmed by analysing appropriate plant material from succeeding crops for their phosphate and potassium concentrations. Through observing the nutrient changes taking place in each crop, adjustments in the fertilizer program can be made over a period of years so that the crops for a given field will have an adequate supply of nutrients for growth.

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# Interrelation of Moisture, Spacing and Fertility to Sugar Beet Production

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MANY STUDIES have been made on the influence of soil moisture on yields of sugar beets (1)[2], (3), (5), (12), (13). Likewise, numerous investigations have been conducted on the effects of various fertilizers on the production of sugar beets (18), (14), (6), (9), (11), (16), (7), (8), (15). Similarly, experiments have been conducted to determine the most satisfactory between-row and within-row spacing (4), (10), (19), (17), (21).

Information obtained from these studies has aided in the economic production of sugar beets. However, it has been difficult to draw satisfactory conclusions on the basis of data from a study of single factors. This is pointed out by Tolman (20) in the statement:

> More frequently than not the interaction relationships between related factors in a field experiment are more important than the primary effect of any one factor.

Coke (2) makes a similar observation:

> In one of our small, compact, beet-producing districts, the average yield of beets varied in a single year from 14 to 39 tons per acre. . . . If for these fields we had a measure of the factors of soil fertility, available soil moisture, soil atmosphere, and diseases and pests, it is very likely some explanation of the large variation in yield would be possible.
>
> Certainly we can learn little, for example, from fertilizer studies, if soil moisture or lack of oxygen in the soil atmosphere is the limiting factor. My plea is that in our research work we should recognize and attempt to measure to the limit of our ability all of the factors affecting plant response. Unless we do this, our progress will be limited.

This study was conducted to obtain information on some of the fundamental relationships among the three factors—fertility, moisture and spacing—as they affect yield of beets, yield of sugar, percentage sugar and juice purity of sugar beets. The conductance of this experiment was made possible through cooperative effort by the following organizations: Utah-Idaho Sugar Company, Amalgamated Sugar Company, Utah Agricultural Experiment Station, a research grant by the Kennecott Copper Company through the Utah State Agricultural College and the Bureau of Plant Industry, Soils and Agricultural Engineering of the United States Department of Agriculture.

## Experimental Design and Procedure

This study was conducted in 1946 on Millville fine sandy loam soil type. The slope was about 1 percent to the south and $\frac{1}{10}$ percent west.

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[2]Numbers in parentheses refer to literature cited.

The soil is calcareous throughout the profile and has a pH of 8.0, 270 parts per million soluble salts, less than 2 percent organic matter, and is low in available phosphate and nitrate. The area had been under dry-farm management, alternately in wheat and summer fallow, for 50 years. In 1945, the first year under irrigation, the area used in this experiment failed to produce a satisfactory pea crop. An adjoining piece of land similarly managed except that it was planted to sugar beets in 1945 produced 8 to 10 tons of beets per acre.

Plots were laid out in a randomized split-plot design. There were 24 main plots in each replication made up of 4 moisture, 3 spacing and 2 manure variables. Each plot was 100 feet long by 32 to 48 feet wide (depending upon row spacing). These variables may be described as follows:

1. Moisture—4
   - $W_1$—Continuously moist (below 750 cm. water tension at 8-inch depth, 6 irrigations)
   - $W_2$—Continuously moist until August 5. No irrigation thereafter, (3 irrigations)
   - $W_3$—After July 15 allowed to reach wilting at 18-inch depth, (3 irrigations)
   - $W_4$—After July 15 allowed to reach wilting at 30-inch depth, (3 irrigations)
2. Spacing—3
   - $S_1$—Rows alternating 12 inches and 20 inches apart (equivalent to 16-inch spacing)
   - $S_2$—Rows 20 inches apart
   - $S_3$—Rows 24 inches apart
3. Manure—2
   - $M_1$—No manure
   - $M_2$—15 tons manure (50 percent dry matter)

Superimposed upon each of the 24 main plots, in each of the 3 replications, were 8 commercial fertilizer plots. Each of these plots were 4 rows wide and 50 feet long. These sub-plots were completely randomized within each large plot. These variables may be described as follows:

4. Commercial fertilizer—8
   - $F_1$—100 pounds phosphoric acid
   - $F_2$—80 pounds nitrogen, 100 pounds phosphoric acid
   - $F_3$—80 pounds nitrogen, 200 pounds phosphoric acid
   - $F_4$—80 pounds nitrogen, 200 pounds phosphoric acid, 150 pounds potash
   - $F_5$—160 pounds nitrogen, 100 pounds phosphoric acid
   - $F_6$—160 pounds nitrogen, 200 pounds phosphoric acid
   - $F_7$—160 pounds nitrogen, 200 pounds phosphoric acid, 150 pounds potash
   - $F_8$—80 pounds nitrogen, 200 pounds phosphoric acid, 150 pounds potash, 50 pounds copper sulfate

All fertilizer, except the second 80 pounds of nitrogen in the 160-pound nitrogen plots, was side-dressed 4 inches below the soil surface the first part of June, and immediately before thinning. The second 80 pounds of nitrogen, on the 3 high-nitrogen plots was applied on the surface of the irrigation furrow August 10. One hundred pounds of phosphoric acid was applied uniformly on all plots. This was done because the prevailing practice in the area was to apply phosphoric acid to sugar beets. In some respects this was unfortunate from an experimental point of view because in effect it eliminated the first phosphorus level as a variable.

Figure 1 is presented to clarify the field design and plot arrangement in this experiment. Replication 1, with the 24 separate main plots, is shown diagrammatically. Plots 1, 2 and 3 from replication 1 are given in greater detail, showing the random arrangement of the 8 commercial fertilizer sub-plots. It happens that these 3 main plots show the 3 spacing variables and 3 of the 4 moisture variables. There were 4 rows of sugar beets on the border of each main plot. These served to isolate the variable moisture, spacing and manurial treatments on each of these main plots.

Total rainfall for the months of June, July, August and September of 1946 was 2.26 inches. Over the past 20 years the average rainfall for this period in this area was 3.37 inches.

U.S. 22 whole seed was drilled April 22 and emerged May 1. Beets were thinned June 10. Two over-head sprinkler irrigations were applied to the entire field. The first over-head irrigation was applied June 26 and the second one July 15. Beginning July 15 the variable moisture treatments outlined above were initiated.

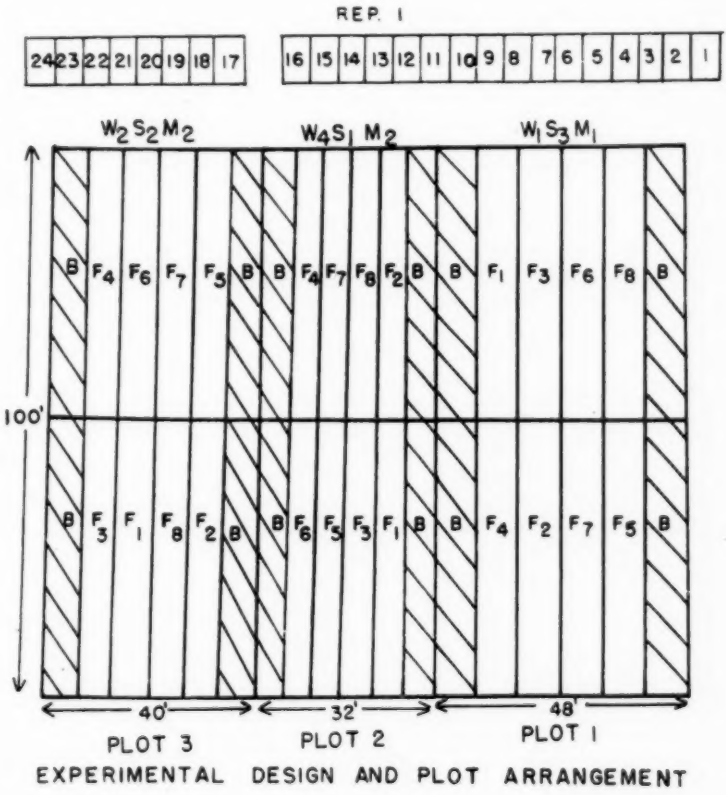
*Soil-Moisture Data:*—The soil-moisture stress in this experiment was followed by means of soil-moisture tensiometers and plaster-of-paris resistance blocks, hereafter referred to as resistance blocks.

Soil-moisture treatment 1 was kept at a low moisture tension throughout the experiment. This was true for all of the plots receiving this treatment. As was seen in the experimental design, the experiment was so arranged that plots having different spacing or different manure treatments could be irrigated differently for each moisture treatment. The soil-moisture tension in moisture treatment 1 was followed by means of tensiometers placed at the 8- and 18-inch depths. The tension at these depths did not exceed 750 centimeters of water at any time. Tensiometers were placed in all of the replications, in all spacings and both manure treatments of the larger plots, which were kept continuously moist throughout the season.

Consistency between moisture records on the three replications for the low moisture tension plots was good. The graph on the bottom of figure 2 is a record of one of the tensiometers on a low moisture-tension plot. A comparison of the curve with the scale on the right of figure 2 shows that the tension was less than 500 centimeters of water most of the season.

Soil-moisture tension in moisture treatments 2, 3, and 4 was followed by use of plaster-of-paris resistance blocks. It is well known that resistance

blocks are somewhat limited in their ability to measure soil moisture adequately, as well as being limited in the range of soil moisture which they will measure. Their main limitations should be stated. They do not measure accurately soil-moisture stress below one atmosphere of tension and they are affected by variations in salts and temperature. Because of these facts there may be considerable error in interpreting moisture tension between 1 and 15 atmospheres. The blocks will, however, give useful information as to whether the tension is below one atmosphere or whether it is approaching a tension equivalent to that at the wilting percentage. The resistance blocks in this experiment were used to indicate when a particular depth of soil was approaching the wilting percentage, and to indicate soil depths from which moisture was being withdrawn. It is believed that the resistance blocks give rather reliable information on these points.


REP. I
24 23 22 21 20 19 18 17
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
W2 S2 M2
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B F4 F6 F7 F5 B B F4 F7 F8 F2 B B F1 F3 F6 F8 B
B F3 F1 F8 F2 B B F6 F5 F3 F1 B B F4 F2 F7 F5 B
100'
40'
32'
48'
PLOT 3
PLOT 2
PLOT 1
EXPERIMENTAL DESIGN AND PLOT ARRANGEMENT

Figure 1.—Main plot arrangement in replication 1 and detail sub-plot arrangement in plots 1, 2 and 3. The letters in the plots indicate the plot treatments defined on pages 2 and 3.

Three sets of resistance blocks were placed in plots of moisture treatments 2, 3, and 4. Each set of resistance blocks consisted of five blocks placed at 8-, 18-, 30-, 48-, and 60-inch depths. Typical data for resistance block records for individual plots receiving moisture treatments 2, 3, and 4 are given in figure 2. It will be noted that the soil-moisture tension did not reach the wilting percentage at the depths indicated in the outline for these treatments until the latter part of the season. This was due to the fact that it was deemed necessary to keep the soil-moisture tension low until the young plants were well established, and also due to the fact, that the sugar beet plants did not dry the soil out as rapidly as had been anticipated. Moisture treatment 2 received two over-head irrigations, June 26 and July 15, and one furrow irrigation, August 5. Moisture treatment 3 approached the tension equivalent to the wilting percentage at the 18-inch depth late in August and was irrigated at that time. Moisture treatment 4 was irrigated about 10 days later even though all the plots on this treatment had not reached the wilting percentage at the 30-inch depth.

The plots receiving moisture treatments 1, 2, 3, and 4 received 6, 3, 3, and 3 irrigations, respectively. As previously noted the first two irrigations for each moisture treatment were light irrigations applied with a commercial over-head sprinkler system. The later irrigations were of the furrow type. No actual measure was made of the water applied but an attempt was made to apply sufficient water to wet the upper 2 feet of soil to field capacity.

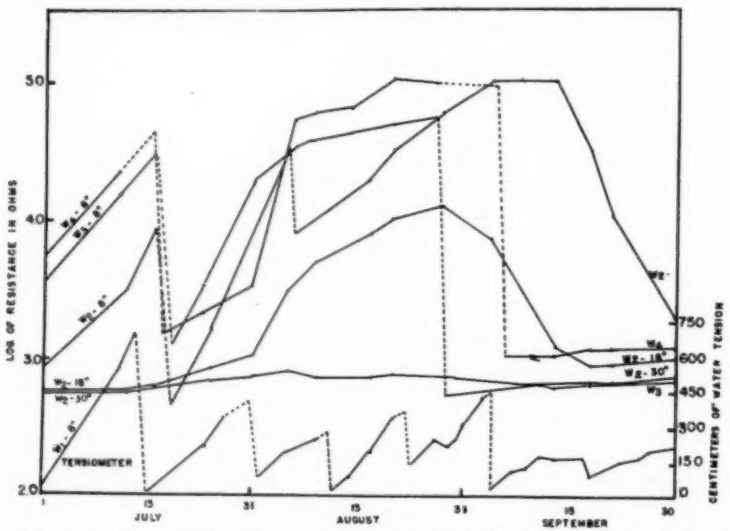



Figure 2.—Curves showing tensiometer record at 8-inch depth of moisture treatment 1 and resistance block records on moisture treatment 2 at 8-, 18- and 30-inch depth, moisture treatment 3 at 8-inch depth and moisture treatment 4 at 8-inch depth.

## Experimental Results

*Plant Data.*—Large variations in yields were obtained on this experiment from individual plots receiving different treatments. The poorest treatment gave a yield of 13 tons per acre while the best treatment gave a yield of 26 tons per acre. The factory average for beets in this area for 1946 was 12 tons per acre.

There were significant differences in yield of beets and tons of sugar for the three main factors: moisture, spacing and manure treatments, on moisture treatment 1. Likewise, on moisture treatment 1 there were significant differences in percentage sugar and purity for variations in applied nitrogen, but no significant differences in percentage sugar or purity for variations in moisture, spacing, or manure. The only significant differences on yield of beets or sugar on moisture treatments 2, 3, and 4 were those between nitrogen fertilizers. There were no significant differences for differentials in phosphorus, potassium, or copper treatments under any of the moisture treatments. This may not be surprising in the instance of phosphorus fertilization since it will be remembered that one level of phosphoric acid was applied uniformly over the entire field.

*Effect of Spacing Variables.*—Figure 3 shows the effect of rate of nitrogen (0, 80, and 160 pounds per acre) on the yield of beets at three spacings. Beets within the row were spaced 1 foot apart in this experiment. Differences required for significance at the 5-percent level for the treatments being compared are indicated by verticle bars on the graph. The shorter bar is a measure of significant differences between any two fertilizer treatments and the longer bar is a measure of significant differences at the 5-percent point between any two spacing treatments. Both bars should be used in a verticle position. It is readily seen that there are significant differences for the three fertilizer treatments at the 12- by 20-inch spacing. Eighty pounds of nitrogen were significantly better than no nitrogen on the 20- and 24-inch spacings, but the 160 pounds of nitrogen did not produce any more beets than the 80 pounds of nitrogen on the 20- and 24-inch spacing. There were significant differences between 24-inch and 20-inch spacing treatments for only the 160-pound level of nitrogen. The 12- by 20-inch spacing was not significantly better than the 20-inch spacing for any of the levels of nitrogen.

Figure 4 gives the tons of sugar produced per acre for the same treatment as was indicated in figure 3. When one compares the 12- by 20-inch spacing with the 24-inch spacing at all nitrogen levels, significant increases in tons of sugar per acre with closer spacing of beets will be noted. The 20-inch spacing produced more sugar than the 24-inch spacing for the no added nitrogen, but there was no significant difference between the 20- and the 12- by 20-inch spacing on any of the nitrogen levels.

Figures 3 and 4 indicate clearly that if one is to obtain a maximum return from high amounts of nitrogen it is necessary to have a sufficient number of plants to utilize it fully. This is evident when one compares

the yield of beets from plots having no nitrogen with those from plots which received 160 pounds of nitrogen at each of the three spacing treatments. There is no significant difference in yield of beets or sugar between 20-inch and 12- by 20-inch rows. Apparently, there was not a sufficient number of plants on the 20 or 24-inch row spacings to benefit from the extra 80 pounds of nitrogen in the 160-pound treatment versus the 80-pound treatment.

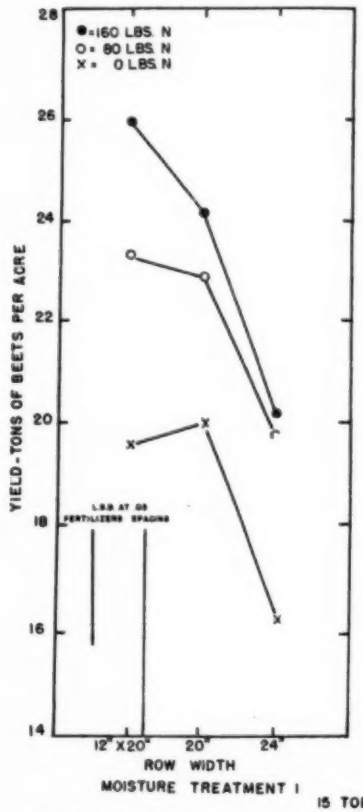



Figure 3.—Yield of sugar beets under various row-width spacing and at three nitrogen-fertilizer levels.

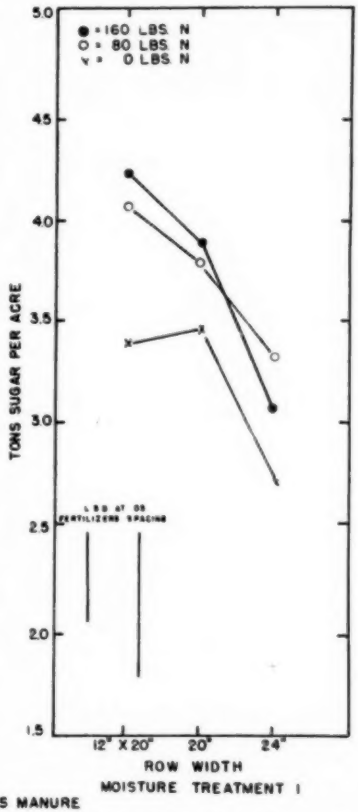



Figure 4.—Tons of sugar obtained from various row spacings and at various nitrogen-fertilizer levels.

The percentage sugar for the same treatments referred to in figures 3 and 4 is given in figure 5. Here it will be noted that the 160-pound nitrogen treatment had a marked effect upon the percentage sugar in the

beets. There is no significant differences between 0 and 80 pounds of nitrogen on any of the spacings used. The data in figure 5 suggests that the higher the rate of nitrogen application and the less densely spaced the plants, the lower the sugar percentage. The same general tendency can be seen in figure 6 when these treatments are compared on a percentage purity of the extract juice basis. The data here show significant differences in the percentage purity due to nitrogen-fertilizer treatments on all spacings. The purity is high in all cases except where high nitrogen is applied in the 24-inch rows.

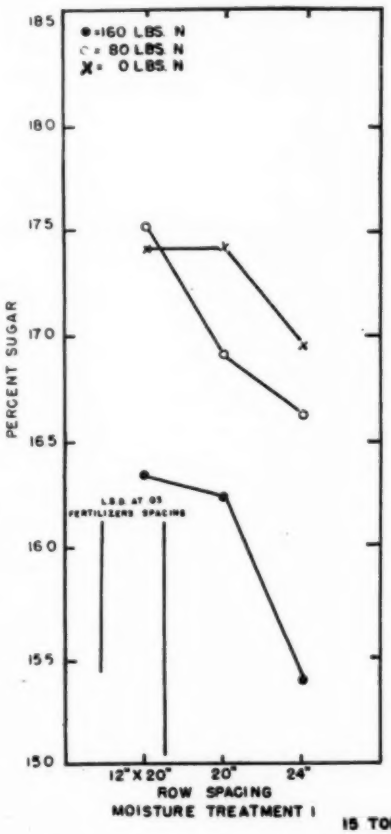



Figure 5.—Percentage sugar in sugar beets as influenced by row width and nitrogen fertilization.

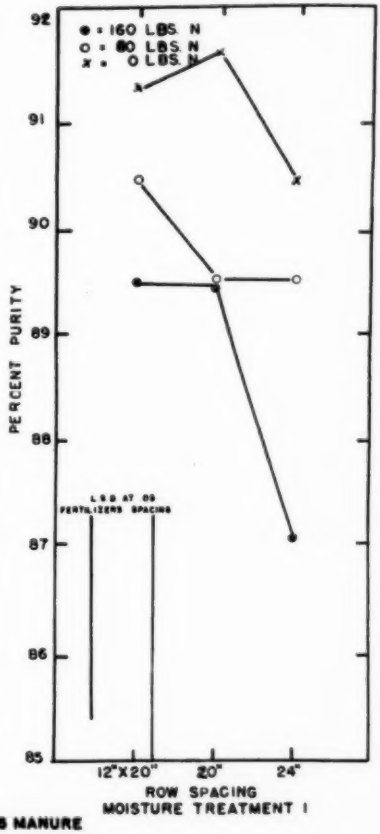



Figure 6.—Percentage purity of extract juice of sugar beets as influenced by row width and nitrogen fertilization.

The importance that should be attached to percentage purity seems to be in controversy. Hence, it is not known that differences of the magnitude obtained in this experiment have any practical meaning.

*Effect of Moisture.*—Figure 7 presents a comparison of moisture levels 1, 3, and 4 at three rates of nitrogen on the yield of sugar beets. Note the significant differences at all levels of nitrogen on the low moisture-stress plots, and the significant differences between low and medium rates of nitrogen on moisture treatment 3, and no difference in yield between low and medium rates of nitrogen under conditions of high moisture stress. Here nitrogen is an effective fertilizer only if moisture does not become limiting. There appears to be at least two possible explanations for the effectiveness of nitrogen on moisture level 1, and its lessened effect on moisture treatments 3 and 4. The first possibility is that added nitrogen (80 and 160 pounds) stimulated early vegetative growth, which in turn hastened the rapid depletion of water from the nitrogen-fertilized plots, and finally resulted in arrested root growth. The second explanation is, that as the surface soil became dry, the added nitrogen became unavailable to the plant, and hence ineffective in growth. At any rate the yield of sugar beets was no greater where 160 pounds of nitrogen was applied than where 80 pounds of nitrogen was used on moisture treatment 3. Yield was no greater for 80 pounds than for no nitrogen under moisture treatment 4. It is not quite clear why 160 pounds of nitrogen stimulated yield on moisture treatment 4.

Data on the chemical analyses of beet leaf petioles indicate that the beets on all plots were getting ample nitrogen in July, but that on plots receiving 0 and 80 pounds of nitrogen on moisture treatment 4, plants were definitely deficient in nitrogen during August and September. Plots receiving 160 pounds of nitrogen per acre did not appear to be deficient in nitrogen at any time.

Resistant block reading indicate that the nitrogen-fertilized plots lost moisture slightly faster than the unfertilized plots, but this difference does not appear to be great enough to explain the response of beets to various nitrogen levels under the three moisture treatments. It appears from the information at hand that the high moisture stresses down to the 18- and 30-inch depths are associated with arrested root growth, and may be the principal factor limiting root growth under the conditions of this experiment.

This graph again emphasizes the fact that if one is to approach a maximum use of fertilizer it is necessary to have low moisture stress or adequate water. It is obvious that correct conclusions would have been difficult to arrive at, with respect to fertilizer treatment, had this experiment been conducted at only one moisture level. One would be forced to one conclusion as to the effect of nitrogen levels for sugar beets if the experiment were conducted only on moisture treatment 4, and to another

conclusion, if the work were conducted on moisture treatment 3. Likewise, if moisture variables were studied on soil of low fertility one would conclude that moisture was of little or no effect on yield of sugar beets.

Figure 8 presents data which show the sugar produced for the same condition referred to and comparisons made in figure 7. Again the importance of having the right combinations of factors is brought out in the data. There is little difference for the three moisture treatments when sugar beets are grown on soil low in available nitrogen. However, there are significant differences in sugar produced when one compares sugar production on moisture treatment 1, with that on moisture treatments 3 and 4, under conditions of medium and high nitrogen levels.

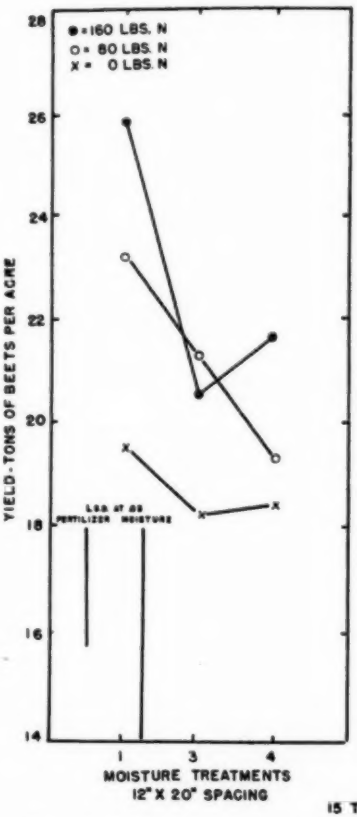



Figure 7.—Yield of sugar beets under three conditions of moisture stress and at three different nitrogen-fertilizer levels.

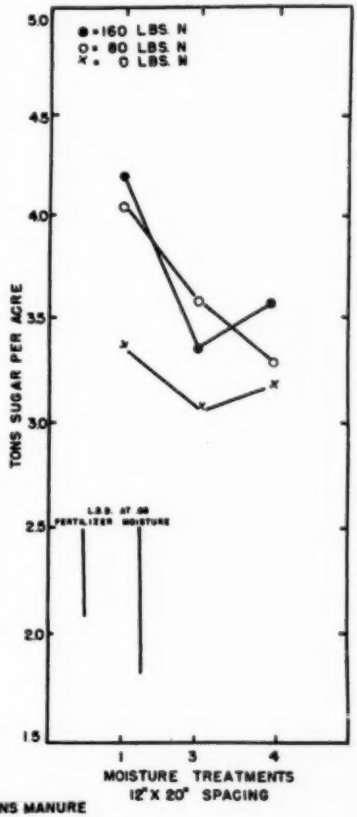



Figure 8.—Tons of sugar produced under three conditions of moisture stress and at three different nitrogen-fertilizer levels.

15 TONS MANURE

Figures 9 and 10 present a comparison of the same factors of moisture and fertility presented in figure 7, in relation to their influence on percentage sugar and percentage purity. It may not be easy to properly interpret and explain the effect of moisture treatment on the percentage sugar and percentage purity. The effect of high levels of nitrogen is seen in about the same manner as was shown in figures 5 and 6. Significant difference in percentage sugar is obtained when a comparison is made between nitrogen treatments under all conditions of moisture stress. It is readily observed that high levels of nitrogen will decrease percentage of sugar. There appears to be little if any effect on sugar percentage for 80 pounds of nitrogen. Purity is definitely affected by high fertilization but it is not quite clear what value should be placed upon this information. It is not definitely known why the percentage sugar and percentage purity should be low in moisture treatment 3. This may be due to the fact that the irrigation treatment made the last of August and the resulting available nitrogen may have stimulated late growth. Late vegetative growth is associated with decreased sugar percentage and percentage purity. Two observations argue against this explanation. Beets receiving no added nitrogen showed a depressed sugar percentage as much as those receiving 160 pounds per acre. Petiole analyses in September showed only slightly greater amounts of nitrogen in leaves from beets growing under conditions of moisture treatment 3 than those from beets on moisture treatments 1 and 4.

*Barnyard Manure.*—The beneficial effects obtained from barnyard manure differed with different moisture treatments, different spacing of plants, and with different levels of nitrogen. In the comparison of manure versus no manure it probably should be pointed out that regardless of the amount of commercial fertilizer added in this experiment there is strong evidence that beneficial effects were still obtained with the 15-ton application of barnyard manure.

Figures 11 and 12 present a good picture of increases due to the addition of manure at different nitrogen levels, and the importance of moisture in the response obtained from manure. It can be seen that there are significant differences between the manure and no manure plots for all levels of nitrogen for the plots receiving moisture treatment 1, that is, those held at a low soil-moisture stress throughout the season. While the tendency under moisture treatment 3 is for the manure plots to yield more than the no manure plots, the differences between manure treatments are not significant. There are significant differences in yield between the low and medium nitrogen levels, even under conditions of high moisture stress. These comparisons in figures 11 and 12 are made at the close spacing of plants and the data in the graphs point again to the importance of approaching optimum conditions for the various factors affecting plant growth.

Figures 13 and 14 show the effect of the treatments discussed in figures 11 and 12, on the yield of sugar per acre. Under conditions of low moisture stress there are significant differences between manure and no manure at all levels of nitrogen. When a comparison is made on the basis

of nitrogen fertilization, on the other hand, the only significant differences in yield of sugar are those between 0- and 80-pound rates of application. Under conditions of high moisture stress (figure 14), there are no significant differences in yield of sugar for either nitrogen fertilization or manurial treatment.

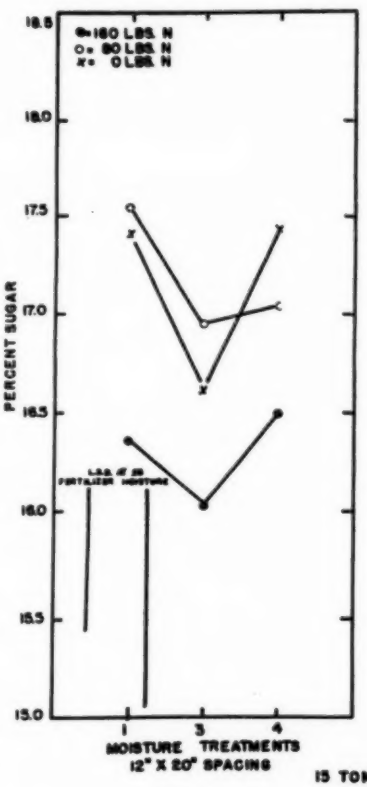



Figure 9.—Percentage sugar as influenced by moisture treatment and nitrogen fertilization.

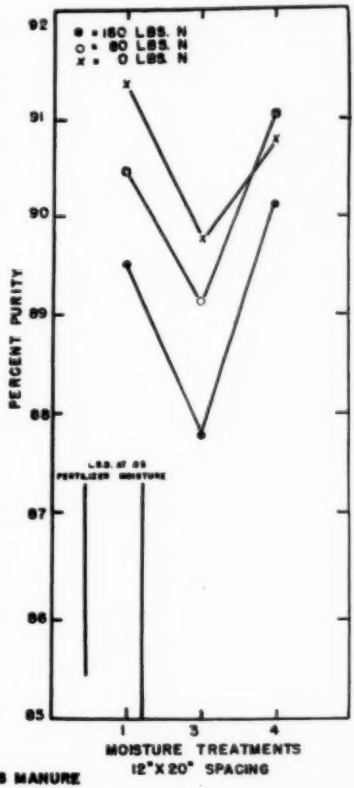



Figure 10.—Percentage purity as influenced by moisture treatment and nitrogen fertilization.

A study of the data in figures 13 and 14 may make it easier to understand why so many apparently conflicting reports have been made on the response of sugar beets to manure and fertilizer. Under soil-moisture conditions of figure 13, differences in yield of sugar are evident while there are no yield differences under conditions of figure 14.

In order to avoid using an undue number of graphs, tables 1 and 2 are given. Data from only four of the eight fertilizer treatments are presented. Since no significant increases in yield were obtained from more than 100 pounds of phosphoric acid, or from 150 pounds of potash, or 50 pounds of copper sulfate, the data from plots receiving variables of these fertilizer treatments are not presented here.

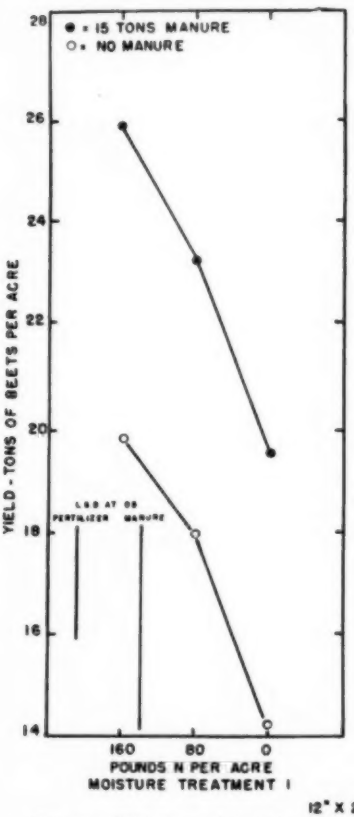
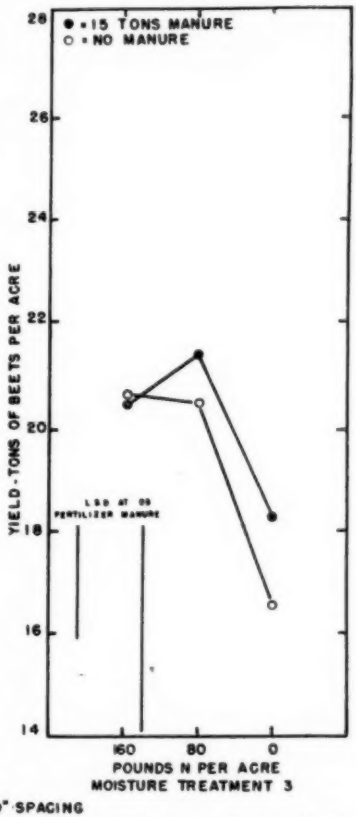



Figure 11.—Yield of sugar beets under condition of low moisture stress as influenced by manure and nitrogen fertilization.




12" X 20" SPACING

Figure 12.—Yield of sugar beets under high moisture stress as influenced by manure and nitrogen fertilization.

Many interesting comparisons may be made from the data in tables 1 and 2. If one should compare the mean yield of beets for each of the three spacing variables he will observe a very interesting tendency. It will be observed in table 1, where manure has been applied, that as the spacing is increased between rows the yield tends to decrease. This tendency is reversed in table 2.

It is plain from a study of tables 1 and 2 that with each successive increment of nitrogen fertilizer there is a tendency for increased yields. Significant differences in yield occur at all spacing variables between the 0- and 80-pound nitrogen applications.

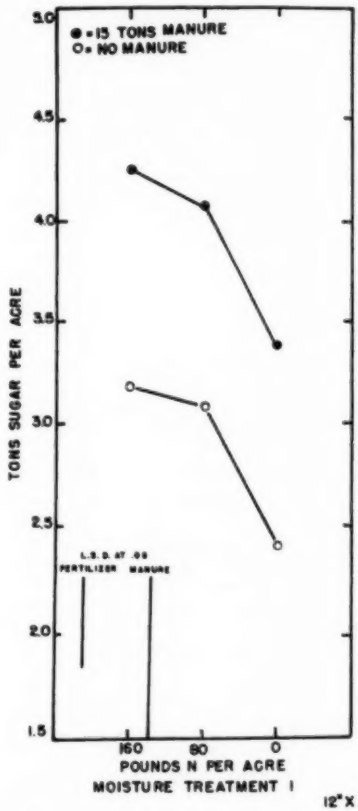
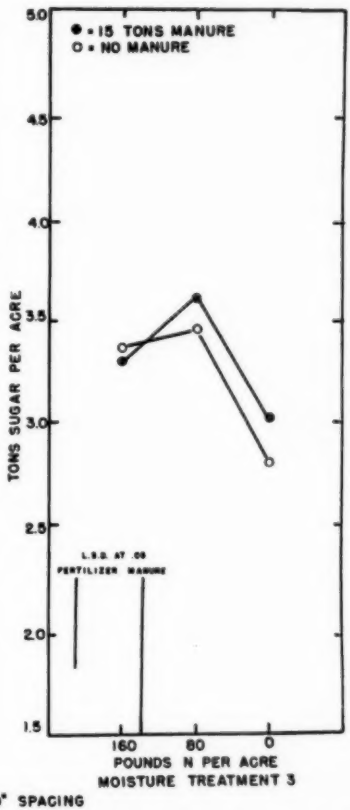



Figure 13.—Yield of sugar under conditions of low moisture stress as influenced by manurial treatment and nitrogen fertilization.




12"X 20" SPACING

Figure 14.—Yield of sugar under conditions of high moisture stress as influenced by manurial treatment and nitrogen fertilization.

Little reference has been made to moisture treatment 2 in the above discussion. For those who are interested in this moisture treatment, the data are available in tables 1 and 2. It will be observed that when manure was used in the closely spaced rows (12- by 20-inch) moisture treatment 2 gave yields very similar to those obtained under moisture treatment 3. With the normal 20-inch spacing the yield under moisture treatment 2 was mid-way between those of moisture treatments 1 and 3. Under con-

ditions of wide row spacing moisture treatment 2 was better than moisture treatments 1 and 4 and equal to moisture treatment 3.

Under conditions of wide row spacing and without manure moisture treatment 2 was easily the best moisture condition.

**Table 1.**—Yield of sugar beets in tons per acre under various fertility, moisture and spacing conditions with 15 tons manure per acre (1946).

| Treatments: Row width 12x20 inches | $N_0P_1K_0$ | $N_1P_1K_0$ | $N_2P_2K_0$ | $N_2P_2K_1$ | Mean |
|---|---|---|---|---|---|
| $W_1$ | 19.6[1] | 23.2 | 25.9 | 24.1 | 23.2 |
| $W_2$ | 17.1 | 20.2 | 22.0 | 23.7 | 20.8 |
| $W_3$ | 18.3 | 21.4 | 20.7 | 22.9 | 20.8 |
| $W_4$ | 18.4 | 19.3 | 21.8 | 20.3 | 20.0 |
| Mean | 18.4 | 21.0 | 22.6 | 22.8 | 21.2 |
| Row width 20 inches | | | | | |
| $W_1$ | 20.0 | 22.8 | 24.2 | 26.4 | 23.4 |
| $W_2$ | 18.1 | 21.3 | 23.4 | 21.8 | 21.2 |
| $W_3$ | 17.0 | 19.1 | 20.2 | 20.7 | 19.3 |
| $W_4$ | 14.3 | 19.9 | 21.0 | 21.8 | 19.3 |
| Mean | 17.4 | 20.8 | 22.2 | 22.7 | 20.8 |
| Row width 24 inches | | | | | |
| $W_1$ | 16.2 | 19.9 | 20.1 | 21.2 | 19.4 |
| $W_2$ | 17.8 | 23.0 | 23.4 | 24.4 | 22.1 |
| $W_3$ | 19.2 | 20.2 | 24.6 | 24.6 | 22.2 |
| $W_4$ | 13.7 | 16.8 | 19.5 | 18.4 | 17.1 |
| Mean | 16.7 | 20.0 | 21.9 | 22.2 | 20.2 |
| Average | 17.5 | 20.6 | 22.2 | 22.6 | 20.7 |

**Table 2.**—Yield of sugar beets in tons per acre under various fertility, moisture and spacing conditions without additions of manure (1946).

| Treatments: Row width 12x20 inches | $N_0P_1K_0$ | $N_1P_1K_0$ | $N_2P_2K_0$ | $N_2P_2K_1$ | Mean |
|---|---|---|---|---|---|
| $W_1$ | 14.2[1] | 18.1 | 19.8 | 20.2 | 18.1 |
| $W_2$ | 17.3 | 21.3 | 21.2 | 20.1 | 20.0 |
| $W_3$ | 16.7 | 20.6 | 20.8 | 21.7 | 19.9 |
| $W_4$ | 15.6 | 18.4 | 20.9 | 19.9 | 18.7 |
| Mean | 15.9 | 19.6 | 20.7 | 20.5 | 19.2 |
| Row width 20 inches | | | | | |
| $W_1$ | 17.9 | 20.7 | 22.4 | 23.0 | 21.0 |
| $W_2$ | 16.0 | 19.8 | 21.9 | 20.4 | 19.5 |
| $W_3$ | 14.4 | 17.5 | 19.8 | 20.4 | 18.0 |
| $W_4$ | 17.5 | 21.9 | 21.9 | 23.4 | 21.2 |
| Mean | 16.5 | 20.0 | 21.5 | 21.8 | 19.9 |
| Row width 24 inches | | | | | |
| $W_1$ | 12.8 | 18.2 | 21.4 | 22.0 | 18.6 |
| $W_2$ | 20.4 | 22.4 | 23.6 | 23.5 | 22.5 |
| $W_3$ | 16.2 | 20.8 | 22.5 | 21.8 | 20.3 |
| $W_4$ | 15.0 | 20.2 | 22.5 | 20.6 | 19.6 |
| Mean | 16.1 | 20.4 | 22.5 | 22.0 | 20.3 |
| Average | 16.2 | 20.0 | 21.6 | 21.4 | 19.8 |

[1]Mean of three replications.
Significant differences at P=.05.
Between fertility levels.....2.50 t/a
Between spacing, moisture or manure variables.....4.16 t/a

## Discussion

The data presented point out the need for having optimum conditions for the various factors affecting plant growth and the need for controlling or measuring all important factors. For instance, to be of greater value a fertility rate experiment conducted under irrigation must have moisture as a variable, or at least as a controlled factor, with a complete moisture-stress record. It is obvious from this experiment that if one is to obtain maximum return from added fertilizer, there must be a sufficient number of plants per acre to make a fairly complete use of all the fertilizer added. In this experiment the largest response occurred only on the wettest plots. In other words, regardless of the number of plants per acre and the nutritional level, maximum production will not be obtained unless the soil moisture is adequate to produce a maximum crop. If only one moisture level were used in an experiment of this type, the fertility response and recommendations based upon it would apply only to that particular treatment, and unless that treatment happened to be one supplying adequate moisture at all times, erroneous conclusions would be drawn with respect to maximum yields and maximum use of fertilizers. It is only when the best combination of all the factors affecting plant growth can be brought together, that we can expect a maximum economic production.

Under conditions of moderate-to-low soil fertility there is a tendency for sugar beets to give a smaller response to added fertilizers when the between-row spacing is wide than when this spacing is close. Also under conditions of wide spacing there is a tendency for the sugar percentage of beets to be lower than under conditions of close spacing. Nitrogen fertilization accentuates this difference.

Sugar beets grown under conditions of high moisture stress show little if any benefit from manurial treatment or nitrogen fertilization. However, when grown under conditions of low moisture stress marked yield increases are obtained from barnyard manure and added nitrogen fertilization.

High nitrogen fertiliaztion and manurial treatment tend to lower the percentage purity of extract juice of sugar beets.

The outstanding fact of this study is, that in order to properly interpret the results of any particular field treatment, as many of the factors of growth as possible should be accurately known, if not controlled.

## Summary

1.—Yield of sugar beets was increased approximately 3 tons per acre for application of 80 pounds of nitrogen under conditions of low moisture stress. This was true for all spacing conditions studied. Sugar beet yields were significantly increased under conditions of low moisture stress only under close spacing (12- by 20-inch rows) for an additional 80 pounds of nitrogen above the initial 80 pounds.

2.—Yield of sugar was increased approximately ½ ton per acre under low moisture stress and with all row-width spacings studied for 80 pounds of nitrogen. An additional 80 pounds of nitrogen did not further increase yields of sugar under any of the spacings studied.

3.—There was a tendency for added commercial nitrogen to lower the percentage sugar and percentage purity of extract sugar beet juice. This difference was not significant for the first addition of 80 pounds of nitrogen. The percentage sugar was lowered from $\frac{3}{10}$ to 1 percent for the second addition of 80 pounds of nitrogen per acre. The purity was lowered approximately 2 percent for all spacing conditions when beets from plots receiving no nitrogen are compared with those receiving 160 pounds nitrogen per acre.

4.—Under conditions of low moisture stress and with close row spacing (12- by 20-inch) yield differences were obtained between each of the three nitrogen levels (0, 80, and 160 pounds) with a difference of 6 ton of beets between 0 and 160 pounds of nitrogen per acre. Under conditions of moderate moisture stress there was no difference in yield between 80- and 160-pound levels of nitrogen and under high moisture stress no difference in yield between 0 and 80 pounds of nitrogen per acre.

5.—Under all conditions of moisture stress and with close spacing there was no difference in yield of sugar between 80 and 160 pounds of ntirogen. Under conditions of low and moderate moisture stress there was about ½ ton of sugar increase for 80 pounds of nitrogen over no nitrogen. Under conditions of high moisture stress there was no significant difference in yield of sugar between any variation in nitrogen fertilization.

6.—Moisture stress had no effect upon percentage sugar or percentage purity. High nitrogen fertilization (160 pounds per acre) depressed both percentage sugar and percentage purity under all conditions of moisture stress studied with the following exception: Under conditions of high moisture stress there was no significant difference in percentage purity between any of the nitrogen treatments.

There was no difference in percentage sugar or percentage purity between sugar beets grown under conditions with no nitrogen and 80 pounds of nitrogen per acre under the conditions of moisture stress studied.

7.—Under conditions of low moisture stress and with the close row-spacing of sugar beets 15 tons of barnyard manure increased yields from 5 to 6 tons per acre irrespective of the amount of nitrogen added (0, 80, or 160 pounds per acre).

Under conditions of moderate-to-high moisture stress there was no increased yield for additions of manure at any level of nitrogen.

8.—Under conditions of low moisture stress and close row-spacing, 15 tons manure increased the yield of sugar 1 ton per acre with all levels of added commercial nitrogen. Under conditions of moderate-to-high moisture stress there was no difference in yield of sugar between manure treatments at any nitrogen level.

9.—The only interactions obtained in this experiment were those obtained under conditions of low moisture stress.

10.—No differences in yield of beets or sugar, percentage sugar, or percentage purity were obtained for differential treatments involving phosphorus, potassium, or copper.

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# Soil Fertility Studies in the Mountain States

Bion Tolman, Ronald Johnson, A. J. Bigler[1]

Soil fertility may be defined as the capacity or quality of the soil necessary to supply plant nutrients in sufficient amounts and in the correct balance for the growth of plants when factors such as temperature, moisture, soil reaction and the physical and biological conditions of the soil are favorable.

This definition of soil fertility recognizes not only the importance of an adequate supply of soil nutrients in a form readily available for plant use, but also the importance of having these nutrients in a proper balance one to another.

This definition recognizes that soil fertility is not just a question of nutrient supply but that it is also one of proper soil environment. To be fertile a soil must be in good tilth, permitting the free development of plant roots and allowing the free movement of soil, air and moisture, while at the same time the humus content should be at a level which will provide high moisture-holding capacity and active biological activity.

The building and maintaining of a high state of soil fertility requires a well-balanced soil-management program. This program must be one which will provide proper drainage, proper irrigation, maintenance of soil organic matter, prevention of soil erosion, and use of properly cared for manure, the utilization of green manures and crop residues from a sound crop-rotation practice, and the supplemental use of the proper kinds and amounts of commercial fertilizers.

The use of commercial fertilizer provides an immediate means of improving soil fertility but should not supplant a long-range program of soil improvement such as the one outlined above.

The economic importance of commercial fertilizer is readily apparent when one considers the fact that the farmers who grow sugar beets spend annually in excess of one million dollars for commercial fertilizers which are applied to the sugar beet crop. If these farmers are to get the most out of this phase of their soil-fertility program, they need an evaluation of their soil-fertility problems and advice as to the kind, quantity and quality of the fertilizer they use. A program to determine these factors may, and should, include such procedures as: plant analysis, soil tests, plot tests and field trials. All of these procedures can be used advantageously. Possibly the first three of these procedures are of most value when used as supplements to the field trials.

This paper deals largely with the results of field tests conducted in Utah, Idaho, Washington, Montana and South Dakota. These tests inves-

[1]Research Director and Research Assistants of the Utah-Idaho Sugar Company. The entire production staff helped carry through the cooperative tests reported here.

tigated such problems as: kind, amount and ratio of fertilizer needed and the time of fertilizer application.

*Experimental Methods and Procedures.*—All fertilizer plots have been cooperative tests between sugar beet growers and the Utah-Idaho Sugar Company. The tests have included a comparison of nitrogen and phosphate fertilizers both when used alone and in combination. The complete set of treatments used is shown in the tables. In all cases the commercial fertilizers were side-dressed to either the planted or the growing crop. Plots were 8 to 12 rows wide and of sufficient length to provide approximately 6 to 8 tons of beets per plot. Figure 1 shows a general view of one of these cooperative plots. Beets from each plot were hauled by truck to the closest receiving point where the weight was obtained.

Figure 1.—General view of one of the commercial-fertilizer plots in South Dakota, September, 1947. Note alternating strip effects caused by the nitrogen fertilizer. The two strips in the center show a contrast of growth between 400 pounds of 16-20-0 left and check strip on the right. Yield difference of 3.17 tons per acre.

About 75 percent of the plots were sampled for sugar content. The sugar samples consisted of four 15-beet samples from each treatment.

Each treatment was run in duplicate on each farm and there were tests on from 8 to 12 farms in each factory district.

*Experimental Results.—Tests in 1945:* The complete results of the 55 field tests conducted in 1945 were reported in the proceedings of the 1946 meetings of the American Society of Sugar Beet Technologists (3).[2] A brief summary of these tests is shown in table 1.

One of the most interesting things brought out by these tests was the fact that in general the farmers were following a phosphate program that was adequately supplying their phosphate requirements, but that the

[2]Numbers in parentheses refer to literature cited.

nitrogen level had been so depleted that on most farms nitrogen was the limiting factor in plant growth.

In cases where the initial phosphate level was high, greatest yield increases resulted from the application of nitrogen fertilizer alone. In tests where the initial nitrogen level was high, greatest yield increases resulted from the application of phosphate fertilizers alone. In about 50 percent of the tests greatest yield increases resulted from the application of a combination of nitrogen and other commercial fertilizers. In a majority of tests the most profitable fertilizer treatment was 400 pounds of ammonium sulfate plus 200 pounds of treble-superphosphate.

*Tests in 1946:* During the 1946 season, 50 fertilizer tests were conducted in the 5 mountain states in which the Company operates. A preliminary report of these tests was made at the Regional meetings of the American Society of Sugar Beet Technologists held in Salt Lake City in 1947 (4). These tests included applications of nitrogen, phosphorus and potash, and the effect of each of the elements tested was measured when they were applied alone as well as when applied in combination with the other elements tested. A complete set of the treatments, showing rates and combinations used, is shown in table 2.

It is evident from the data in table 2 that there was little or no indication of a yield response to potash but that there was a definite response from nitrogen and from nitrogen and phosphate used in combination. In many tests there was no response from phosphate used alone. In this regard, the general response pattern was similar to that of the 1945 tests. In almost every area, 300 pounds of 16-20-0 mixed fertilizer gave a greater response than did 300 pounds of either ammonium nitrate or treble-superphosphate used alone. The average yield increase from 300 pounds of 16-20-0 per acre was 2.11 tons.

The addition of minor elements to a 16-20-20 fertilizer did not have any significant effect on either yield or sucrose content.

Applications of 300 pounds of 16-20-0 mixed fertilizers depressed the sucrose content of beets an average of .30 percent. A 600-pound application of 16-20-0 depressed sucrose content an average of .74 percent.

*Date of Fertilizer Application.—Tests in 1946:* Some preliminary tests were conducted during the 1946 season to check on the comparative efficiency of applications made early or late in the growing season. Four dates of fertilizer application were compared. At planting time, at thinning time, at the last cultivation and on a fourth series the fertilizer was split—one-third of the total amount was applied at each of the other periods. The complete treatments and the results are shown in table 3.

It is evident from the data that in these tests, time of application had very little effect on yield response, although there was a general response from the fertilizer applied.

**Table 1.**—Fertilizer tests conducted in 1945 classified as to type of response as related to initial level of nitrogen and phosphorus and the importance of keeping a proper balance between N and P.

| Classification of test as to limiting factor (P or N) | A. S.: | None | 200 | 400 | None | None | 200 | 400 | 200 | 400 |
|---|---|---|---|---|---|---|---|---|---|---|
| | T. S. P. | None | None | None | 200 | 400 | 200 | 200 | 400 | 400 |
| | | | | | | (tons of beets) | | | | |
| Nitrogen limiting factor (average of 18 tests)[1] | | 13.00 | 15.30 | 16.36 | 13.11 | 12.23 | 14.24 | 15.42 | 14.81 | 15.48 |
| Phosphate limiting factor (average of 9 tests)[2] | | 18.87 | 17.11 | 17.00 | 19.49 | 21.16 | 20.94 | 20.84 | 19.69 | 20.30 |
| Response to increased level of both N and P (average of 28 tests)[3] | | 19.53 | 21.17 | 22.13 | 20.62 | 20.67 | 22.34 | 23.60 | 20.98 | 22.63 |

[1]These farms all had the equivalent of 150 pounds of treble-superphosphate broadcast and worked into the seedbed before they were selected as test fields.
[2]These farms were all livestock farms and had been heavily manured, consequently initial nitrogen level was good.
[3]These were farms of better-than-average fertility where both the nitrogen and phosphate levels were being fairly well maintained, as evidenced by check yields.

**Table 2.**—Average yields (tons of beets) from commercial-fertilizer tests including various rates and combinations of such elements as: nitrogen, phosphorus, potash and a composite of minor elements. Tests conducted in 1946.

| Amount and kind of fertilizer applied (per acre) | Salt Lake and Utah Co. | Gunnison | Box Elder County | Idaho | Montana | South Dakota | Wash-ington | Average[1] response from all tests | Average sucrose content |
|---|---|---|---|---|---|---|---|---|---|
| 1—Unfertilized check | 13.98 | 15.75 | 14.15 | 13.46 | 13.97 | 10.83 | 19.89 | 14.52 | 15.81 |
| 2—150 lbs. treble-superphosphate | 14.89 | 16.46 | 15.08 | 13.95 | 13.31 | 11.59 | 19.82 | 14.97 | 15.74 |
| 3—300 lbs. treble-superphosphate | 16.53 | 16.84 | 15.64 | 13.98 | 13.96 | 12.42 | 20.11 | 15.60 | 15.80 |
| 4—150 lbs. ammonium nitrate | 15.71 | 16.46 | 17.09 | 14.72 | 14.27 | 11.83 | 22.03 | 15.99 | 15.50 |
| 5—300 lbs. ammonium nitrate | 16.03 | 16.45 | 17.47 | 15.05 | 14.89 | 12.16 | 22.99 | 16.43 | 15.46 |
| 6—200 lbs. potassium chloride | 15.14 | 16.28 | 14.60 | 13.72 | 13.26 | 11.38 | 20.15 | 14.91 | 15.65 |
| 7—600 lbs. 16-20-0 mixed fertilizer | 17.06 | 17.45 | 18.49 | 15.65 | 15.29 | 12.86 | 24.15 | 17.27 | 15.07 |
| 8—300 lbs. 16-20-0 mixed fertilizer | 16.30 | 17.19 | 16.88 | 15.33 | 15.14 | 12.30 | 23.34 | 16.63 | 15.58 |
| 9—600 lbs. 16-20-20 complete fertilizer | 16.42 | 16.41 | 17.43 | 15.55 | 16.00 | 13.00 | 24.94 | 17.15 | 15.09 |
| 10—600 lbs. 16-20-20 plus minor elements | 17.33 | 17.17 | 17.18 | 15.19 | 15.89 | 12.60 | 25.32 | 17.26 | 15.11 |
| Number of tests averaged in each area | 8 | 5 | 6 | 9 | 6 | 8 | 8 | 50 | 18 |

[1]Weighted averages representative of the average response from all 50 tests.

**Table 3.**—Summary of the yield of beets in tons per acre resulting from the application of commercial fertilizer at different periods of plant development. (Tests conducted in 1946.)

| Amount of fertilizer applied and time of application | Location of test | | | | Combined averages |
|---|---|---|---|---|---|
| | Washington | Utah County | Salt Lake County | South Dakota | |
| **Planting time** | | | | | |
| 300 lbs. 16-20-0 | 27.95 | 16.74 | 15.01 | 12.86 | 18.84 |
| 600 lbs. 16-20-0 | 32.05 | 17.52 | 16.76 | 13.03 | 19.84 |
| Average | 29.99 | 17.13 | 15.89 | 12.95 | 18.99 |
| **Thinning time** | | | | | |
| 300 lbs. 16-20-0 | 30.08 | 16.92 | 14.74 | 12.16 | 18.47 |
| 600 lbs. 16-20-0 | 31.56 | 18.70 | 14.35 | 12.55 | 19.29 |
| Average | 30.82 | 17.81 | 14.55 | 12.35 | 18.88 |
| **Last cultivation** | | | | | |
| 300 lbs. 16-20-0 | 29.99 | 16.30 | 15.33 | 12.06 | 18.42 |
| 600 lbs. 16-20-0 | 30.75 | 17.66 | 15.44 | 12.52 | 19.09 |
| Average | 30.37 | 16.98 | 15.33 | 12.29 | 18.74 |
| **Split application** | | | | | |
| 300 lbs. 16-20-0 | 29.89 | 16.54 | 13.18 | 12.62 | 18.06 |
| 600 lbs. 16-20-0 | 29.10 | 18.45 | 14.38 | 13.56 | 18.87 |
| Average | 29.50 | 17.49 | 13.78 | 13.09 | 18.46 |
| **Combined average** | 30.17 | 17.35 | 14.90 | 12.67 | 18.77 |
| **Yield of check plots** | 25.80 | 13.81 | 13.78 | 11.95 | 16.34 |

*Tests in 1947:* The fertilizer tests conducted in 1947 included a study of the time and rate of application of nitrogen fertilizer. Each rate of nitrogen application was compared with and without the addition of phosphate fertilizer. All the phosphate treatments were applied at planting time, and one-half of the nitrogen treatments was applied at the same time. The other half of the nitrogen plots did not receive the nitrogen application until after thinning. Thus in each test there was a comparison of the time of applying nitrogen, but phosphate was in every case applied early. In this respect the 1947 tests varied from the time of application plots conducted in 1946, for in the 1946 tests both the nitrogen and phosphate were applied at different times.

It can be seen from the data in table 4 that the 1947 tests supported the results obtained in previous years. In many tests there was little or no yield increase from the application of phosphate fertilizer when it was applied alone, however, in two or three tests there was a very striking phosphate response, and one of these tests is reported separately in the Montana area (figure 2). The average yield increase from the 200-pound application of treble-superphosphate per acre in all 31 tests was .89 ton. There was a response to nitrogen fertilizer in 30 of the 31 test plots. The average yield increase from 200 pounds of ammonium nitrate was 1.72 tons per acre and there was further increase of 1 ton per acre from an additional 200-pound application of ammonium nitrate. The highest average yields resulted from a combination of 400 pounds of ammonium nitrate plus 200 pounds of treble-superphosphate per acre. This is equivalent to about 600 pounds of a 21-14-0 mixed fertilizer. A view of one of the plots which showed a marked nitrogen response is shown in figure 3. In a majority of tests, the most profitable yield increases resulted from the application of 200 pounds of ammonium nitrate and 200 pounds of treble-superphosphate. This is equivalent to 400 pounds of 16-20-0 per acre.

**Table 4.**—Summary of the tons per acre for 31 commercial-fertilizer tests which included varying rates of nitrogen at two different dates of application. Tests conducted in 1947.

| Location of tests | Number of tests | Check | 200 lbs. TSP[1] | A N at planting time | | | | | A N after thinning | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 200 lbs. A N[2] | 200 lbs. A N plus 200 lbs. TSP | 400 lbs. A N | 400 lbs. A N plus 200 lbs. TSP | Average | 200 lbs. A N | 200 lbs. A N plus 200 lbs. TSP | 400 lbs. A N | 400 lbs. A N plus 200 lbs. TSP | Average |
| Montana | 1 | 5.98 | 8.22 | 5.95 | 8.18 | 5.42 | 9.23 | | 5.31 | 8.87 | 6.79 | 9.16 | |
| Montana | 4 | 11.02 | 11.66 | 11.70 | 12.69 | 12.09 | 12.57 | 12.26 | 12.42 | 12.46 | 11.99 | 12.84 | 12.43 |
| South Dakota | 4 | 9.11 | 9.59 | 11.22 | 11.32 | 12.18 | 12.72 | 11.86 | 11.65 | 11.59 | 12.37 | 11.93 | 11.88 |
| Washington— | | | | | | | | | | | | | |
| Toppenish | 4 | 21.78 | 23.28 | 24.64 | 24.66 | 25.09 | 25.50 | 24.97 | 25.43 | 25.79 | 26.19 | 26.03 | 25.86 |
| Walla Walla | 2 | 26.13 | 26.17 | ---- | ---- | ---- | ---- | ---- | 29.22 | 30.17 | 31.02 | 32.10 | |
| Idaho | 3 | 13.83 | 14.00 | 16.22 | 16.75 | 16.61 | 17.10 | 16.67 | 16.79 | 16.78 | 16.89 | 17.06 | 16.88 |
| Utah— | | | | | | | | | | | | | |
| Gunnison | 2 | 19.67 | 19.69 | 21.33 | 19.98 | 21.38 | 20.52 | 20.80 | 21.68 | 21.26 | 20.03 | 20.23 | 20.80 |
| Garland | 4 | 19.20 | 20.89 | 21.63 | 22.64 | 23.03 | 24.48 | 22.95 | 22.28 | 23.20 | 21.84 | 23.16 | 22.62 |
| Salt Lake and Utah Co. | 7 | 17.23 | 18.31 | 19.63 | 20.02 | 20.14 | 20.40 | 20.05 | 19.33 | 19.83 | 20.05 | 20.06 | 19.82 |
| Average of 29 tests | 31 | 15.76 | 16.65 | 17.48 | 18.18 | 18.46 | 18.94 | 18.26 | 18.11 | 18.48 | 18.37 | 18.65 | 18.40 |
| Average sucrose percentage | 20 | 15.65 | 15.75 | 15.48 | 15.41 | 15.07 | 15.03 | 15.25 | 15.47 | 15.45 | 15.12 | 14.95 | 15.25 |

[1]TSP=treble-superphosphate
[2]A N=ammonium nitrate

There was little or no difference in the yields from plots receiving the nitrogen at planting time as compared to those which were side-dressed after thinning. In the Yakima Valley, the area with the longest growing season, the tests seemed to indicate some advantage from the later nitrogen application. From the averages of all the tests there is some indication that the most profitable time of nitrogen application may depend on the amount to be applied. When only 200 pounds of ammonium nitrate were applied, there was some advantage to side-dressing it after thinning. When 400 pounds of ammonium nitrate were applied, greatest average yields resulted from side-dressing the nitrogen immediately following planting. However, these differences were small as compared to the general fertilizer response resulting from the application of the fertilizer at either one of the dates. Thus the tests indicate that, within the limits of the time tested, it was much more important to get the fertilizer applied than it was to give too much consideration as to just when it should be applied.

Figure 2.—Commercial-fertilizer plot typical of the few where phosphate was so limiting that nitrogen alone gave no response. Plot on left with 400 pounds of ammonium nitrate per acre yielded 5.42 tons per acre as compared to 9.23 tons per acre from plot on the right which had 600 pounds of 16-20-0. Check plot yielded 5.98 tons per acre. Plot near Great Falls, Montana. Very few fields were found this deficient in phosphate.

Application of 400 pounds of 16-20-0 decreased the sucrose content an average of .24 percent. This corresponds rather closely with the .23 percent decrease resulting from the application of 300 pounds of 16-20-0 in the 1946 tests. Application of 600 pounds of 21-14-0 per acre decreased sucrose percentage an average of .60 percent. It is apparent that the second 200 pounds of fertilizer decreased sugar percentage more than did the first 200 pounds applied. The production of gross sugar per acre from the check plots was 2.4664 tons per acre. The 400-pound application of 16-20-0 produced 2.820 tons of gross sugar per acre and the 600-pound application

of 21-14-0 per acre produced 2.818 pounds of gross sugar per acre. These figures again emphasize the fact that the most profitable fertilizer application was the 400 pounds of 16-20-0 per acre.

*General Observations.*—During the 3 years of these tests, which involved work with a total of about 150 cooperating farmers, several significant observations have been made which do not properly fall under the heading of experimental results. However, some of them do have a bearing on practical fertilizer practice and for that reason these observations are recorded here.

Figure 3.—Commercial-fertilizer plot typical of those where the major response came from nitrogen fertilizer. Check on right yielded 14.53 tons per acre. Plot on left with 600 pounds of 16-20-0 per acre yielded 21.36 tons per acre. Plots receiving 400 pounds of ammonium nitrate alone yielded 20.67 tons per acre. This test located near Garland, Utah.

Many farmers entertain the misconception that nitrogen fertilizers are extremely transitory and that nitrogen must be applied in small frequent amounts just as it is needed by the plant. This idea is carried to the extreme by some who claim that nitrogen only holds in the soil for a period of 12 to 14 days and that it frequently volitalizes as a vapor and is lost into the atmosphere. These tests and many others which might be cited prove that applications of nitrogen remain effective throughout the growing season.

It is well established that nutrient elements must be in solution before they can be utilized to any great extent by growing plants. Commercial fertilizers should, therefore, be applied at sufficient depth in the soil to assure that they will at all times be in contact with adequate soil moisture. Fertilizers are easily side-dressed 3 to 5 inches deep prior to thinning,

but when the side-dressing is delayed until after thinning, the soil in many cases is so dry and hard that side-dressing is difficult and the fertilizer in many cases is placed near the surface where the soil soon dries out after each irrigation until the beets become large enough to shade the ground. One other disadvantage has been encountered when application of the fertilizer has been delayed until after thinning. Generally by the time thinning has been completed, the first crop of alfalfa hay needs to be cut and beans and potatoes need to be planted. By the time these jobs have been taken care of, the beets are suffering for water and the irrigation must be further delayed until the fertilizing can be taken care of. As a result of these difficulties, the authors have seen many cases where the fertilizer has lain in the shed all season instead of being applied to the beet crop. Early application of fertilizer avoids almost all these difficulties.

One other difficulty encountered was the failure of the farmer to increase his irrigation to take care of his increased level of fertility. In several cases the authors observed plots where the check strip showed no signs of moisture shortage but where the foliage of beets on the heavily fertilized strips were badly wilted and in some cases were starting to burn. In some other cases definite bands of fertilizer were in evidence in the soil at harvest time. Irrigation practice should be geared to the fertilizer practice. Fertilizing in each row and then irrigating in every other row does not make for efficient fertilizer use. Neither can maximum fertilizer response be obtained without adequate moisture to support the increased growth.

## Discussion and Summary

The results of fertilizer tests conducted in the mountain states during the past 3 years indicate that sufficient attention has not been paid toward the maintenance of soil nitrogen. In many cases farmers have been applying phosphate fertilizers over a period of years but during the same period little or nothing has been done to maintain the nitrogen level in their soils. As a result, nitrogen was shown to be a limiting factor in crop production on a majority of the farms on which tests were located.

These tests have further pointed out the importance of establishing and maintaining a balanced level of fertility. Phosphate applications on fields where nitrogen was limiting gave no yield response and in several cases seemed to depress yields. Also where phosphate was limiting, nitrogen applications were ineffective in increasing yields but did cause a decrease in sucrose content so that the end result was a definite drop in sugar per acre.

The importance of maintaining a balance in soil fertility has been recognized for more than a century, and many research workers have reported that an increase of one element in the soil, generally results in an increase of this element in the plant, and that an increase of any one element in the plant is generally offset by a decrease of other elements in the plant. A rather complete review of this literature has been given by C. A. Browne (1).

In view of the fact that one element cannot be substituted for another and that an excess of one nutrient element actually interferes with the proper utilization of others, it becomes of increasing importance that fertilizer usage be based on actual need. Schreiner (2) has summarized this phase of the program as follows: "Evaluation of the fertility of a soil and of the quantity and quality of a fertilizer required for profitable yield and quality of crop is indispensible to economic fertilizer usage and essential to efficient crop production."

One encouraging factor indicated by these tests is the similarity of response over the five mountain states in which the tests were located. The following facts seem to apply pretty generally to each and all of the areas tested:

1. There was a general nitrogen deficiency.

2. There was a general phosphate response.

3. Greatest yield increases resulted from applying both nitrogen and phosphate.

4. Little or no evidence was found to indicate a potash deficiency, or that any great general benefits would result from the additional minor elements.

5. Date of nitrogen application proved to be relatively unimportant as compared to the importance of at least getting it applied.

6. An application of 300 to 400 pounds of 16-20-0 or its equivalent per acre seemed to be the most profitable application.

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# Harvest Results of Inorganic Fertilizer Tests on Sugar Beets Conducted in Four States, 1947[1]

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Fertilizer trials on farmers' fields have a definite part in the determination of soil nutrient deficiencies and the response obtained from fertilizer treatment. The number of such trials that can be made are generally limited by economic and physical factors. To be sure, if one were to exhaust the treatments, fields, and crops that could enter into a study of this type, the number of plots required would be innumerable. Even then one would arrive at only certain deductible conclusions that would have limited application unless other factors were observed and correlated with the tests. To observe and study the many aspects of several fertilizer trials from the selection of fields to condensing and reporting the data is an immense job. It was felt this could best be attacked, as has been the case in so many other problems, through cooperative effort.

The data presented here is limited to the first year's harvest results. The study of cropping history, past fertilizer practices, soil classification and analysis, tissue analysis and other factors under observation have not been assimilated or completed at this time.

The reader will note that there is a certain amount of standardization in the conduct of these tests carried out in sections of four states. Nevertheless, due to the variation in the number of tests and the variation between tests within the states the writers have chosen to present the results of each state in a somewhat different manner.

In this paper identity of the results for each state is maintained; however, in presentation, especially of materials and methods, generalizations covering the four states are made wherever possible.

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[1]Investigations of the Department of Agronomy of the State Agricultural Experiment Stations and the Extension Service of the State Agricultural Colleges of Colorado, Nebraska, Wyoming and Montana in cooperation with The Tennessee Valley Authority and the Great Western Sugar Company.

Paper No. 274—Colorado Agricultural Experiment Station.

Paper No. 448—Journal Series, Nebraska Agricultural Experiment Station.

Paper No. 203—Journal Series, Montana State Agricultural Experiment Station.

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## Materials and Methods

Initially there were selected in each fieldman's district of the Great Western Sugar Company two or more fields to be planted to sugar beets in 1947. From this array of fields one field per fieldman's district was selected on the basis of uniformity of soil, cropping and yield history, and desirability of location for demonstrational purposes. Generally fields of low, medium, and high productivity were selected within a factory district.

Six or eight row plots the length of the field were used. The experimental design was that of a randomized complete block including nine treatments and two or three replications. The treatments are presented in tabular form in table 1 for tests conducted in Colorado, Wyoming and Montana.

**Table 1.**—Kind, amount in pounds per acre, time and manner of application of fertilizers used for each treatment in tests conducted in Colorado, Wyoming and Montana (treatments applicable to Nebraska tests exclusive of treatments 7 and 8).

| Treatment | | Planting | | | | Thinning | |
|---|---|---|---|---|---|---|---|
| | | In row with seed | Side-dressed | | | Side-dressed | |
| No. | Symbol | $P_2O_5$ | $P_2O_5$ | N | $K_2O$ | N | Minor elements |
| | | (pounds) | (pounds) | (pounds) | (pounds) | (pounds) | (pounds) |
| 1 | P | 23 | 92 | -- | -- | -- | -- |
| 2 | N | -- | -- | -- | -- | 64 | -- |
| 3[1] | 2(N/2) (split application) | -- | -- | 32 | -- | 32 | -- |
| 4 | NP | 23 | 92 | -- | -- | 64 | -- |
| 5 | NPK | 23 | 92 | -- | 60 | 64 | -- |
| 6 | 2(NPK) | 23 | 184 | -- | 120 | 128 | -- |
| 7 | NPK+ (minor elements) | 23 | 92 | -- | 60 | 64 | 100 |
| 8 | Check 1 | Undisturbed check | | | | | |
| 9 | Check 2 | Equipment pulled through field at each date of side-dressing | | | | | |

$P_2O_5$ from superphosphate, approximately 46 percent $P_2O_5$.
N from ammonium nitrate, 32 percent N, except for Montana and Lovell, Wyoming, districts where ammonium sulfate, 20.5 percent N, was used.
$K_2O$ from muriate of potash, 60 percent $K_2O$.
Minor elements from a mixture of 22.2 pounds $MnSO_4$, 22.2 pounds $ZnSO_4$, 22.2 pounds $Na_2B_4O_7 \cdot 10H_2O$, 22.2 pounds $FeSO_4$ and 11.1 pounds $CuSO_4$.

[1]For Wyoming, treatment 3 includes application of superphosphate as in treatment 4.

The treatments used in Nebraska are identical with those listed in table 1, except for treatments 7 and 8. The minor elements which characterized treatment 7 for the other states were not used, and neither was the undisturbed check. In Nebraska, treatment 7 was similar to treatment 4 except that N was applied at planting time instead of after thinning. Treatment 8 was made to differ from treatments 4 and 7 in that 32 pounds N was side-dressed at planting time and 32 pounds side-dressed at thinning time.

Generally, beet drills with fertilizer attachments were used in making the fertilizer applications. The standard equipment was in many cases modified to fit the need. Tractor-mounted fertilizer side-dressing equipment was also used in some areas. In Montana, the side-dressing at planting time was conducted so that the fertilizer was placed about 2 inches to the side

of the row and at the depth of the seed. Side-dressing applications in the other states were made somewhat deeper and further from the row as was also the case for the Montana tests side-dressed at thinning time.

The harvest results were obtained by hand-sampling 32 ten-foot lengths of row taken at intervals from the four center rows of each plot. All these beets were carefully topped, washed, counted and weighed. One-fourth of this quantity was then used in the determination of sugar content. The sampling was completed the week prior to the opening of the beet-receiving stations. These harvesting rules were not followed without exception as in a very few cases the entire plots were harvested individually by the farmer, and tare and sugar samples taken from each load.

## Results for Colorado

The mean effects of nine fertilizer treatments on the yield of beets, gross sugar, and percentage sugar for the Colorado tests are given in table 2. The data are averages of the results from 37 farms participating in the experiment. The summarized results in table 2 have a threefold purpose, (1) they show the comparative effects of the different treatments as a whole, (2) they provide an estimate of the significance of the average results and (3) they serve as a basis for estimating the yield increase which might be expected from any of these treatments if applied to all the sugar beets in northeastern Colorado territory.

**Table 2.—Mean increase in yield per acre over check 2 and difference in percentage sugar due to treatment.**

| | Treatment | | | | | | | | | LSD[2] 5-percent point |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 P | 2 N | 3 2(N/2) | 4 NP | 5 NPK | 6 2(NPK) | 7 NPK+ | 8 $Ck_1$ | 9[1] $Ck_2$ | |
| Tons beets | 0.56 | 1.22 | 1.22 | 1.75 | 1.75 | 2.14 | 1.54 | 0.25 | 17.16 | .522 |
| Percent sugar | .01 | —.47 | —.53 | —.51 | —.45 | —1.12 | —.54 | .05 | 14.15 | .262 |
| Pounds sugar | 148 | 195 | 165 | 318 | 338 | 175 | 216 | 50 | 4919 | 155 |

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1).

The summary presented in table 2 does not constitute a reliable basis for predicting response from the treatments on individual farms nor for predicting response from any one of the other possible rates or combinations of fertilizers which might be used but which were not included in this experiment. It does, however, bring out the following significant facts:

1. Nitrogen and phosphorus alone or in combination resulted in increased average yields.

2. Nitrogen alone gave about twice as much average increase in yield of beets as phosphate alone and slightly greater increase of total sugar.

3. The average increases in beet yield from nitrogen and phosphate were approximately additive when the two were applied in combination.

4. No significant increase was obtained from the addition of potash or minor elements. A possible decrease due to minor elements is indicated.

5. Percentage sugar was decreased approximately one-half of 1 percent by the application of nitrogen at the rate of 200 pounds of $NH_4NO_3$ per acre, and 1 percent when twice this rate was added. It should be noted, however, that the beets in this experiment were harvested in advance of the regular harvest and it is quite possible, if not probable, that the differences in sugar percentage would have been less pronounced later in the season.

*Statistical Behavior of the Data.*—Before making the comparisons of the effects of the various treatments the data were tested for homogeneity to determine if a generalized standard error could be used as a basis of estimating significance of differences between treatments. For the combined data including all the separate experiments it was found that the data were homogeneous with respect to treatments but not with respect to farms. The data were not homogeneous with respect to treatments in the individual experiments. Comparison of the differences of the means of the treatments in the combined experiment on the basis of the generalized standard error of the difference is, therefore, justifiable but similar comparisons cannot be made between different treatments in the individual experiments.

*Results of Individual Experiments.*—Wide variability between soils and between other factors affecting response to fertilizers on different tracts of land limit the breadth of generalizations which can be drawn from a single experiment or groups of experiments. Before generalizations from an experiment on one tract of land can be applied to other tracts, some ideas of the variability between tracts is necessary. The percentage response data in table 3 and the frequency distribution curves in figures 1 and 2 show wide differences in response to the fertilizer treatments on different farms. The variability includes differences due to experimental error in addition to the actual differences due to response to treatment but in either case the generalizations which can be made are affected. It is probable that a large part of the negative response can be attributed to error, but since nitrogen significantly reduced sugar percentages it is logical to assume that some actual decrease due to nitrogen may have occurred in the yield of sugar and under some conditions actual decreased yields of beets may have resulted from fertilizer application.

**Table 3.**—Response of individual farms to P, N, NP and NPK.

| Treatment | Beet Yield | | Sugar Yield | |
|---|---|---|---|---|
| | Positive | Negative | Positive | Negative |
| | (percent) | (percent) | (percent) | (percent) |
| 1 P | 70.3 | 29.7 | 70.3 | 29.7 |
| 2 N | 67.6 | 32.4 | 48.6 | 51.4 |
| 4 NP | 83.8 | 16.2 | 67.6 | 32.4 |
| 5 NPK | 81.1 | 18.9 | 70.3 | 29.7 |

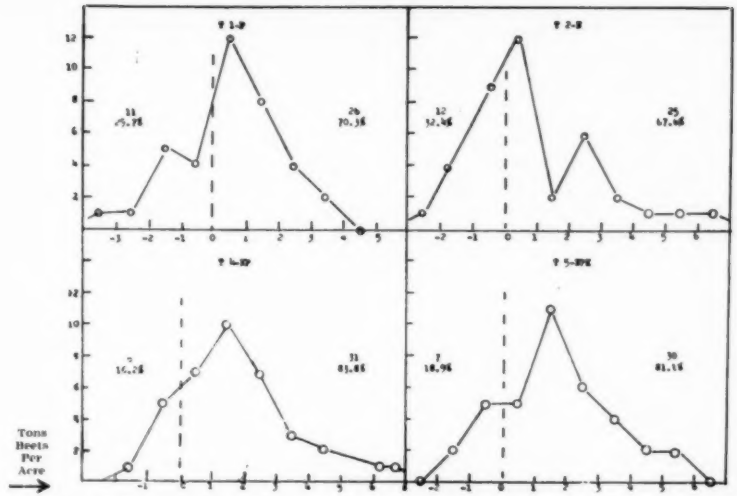


Figure 1.—Frequency distribution curves showing the number and percentage of farms in various beet yield increase groups for treatments 1, 2, 4 and 5 compared with check 2.

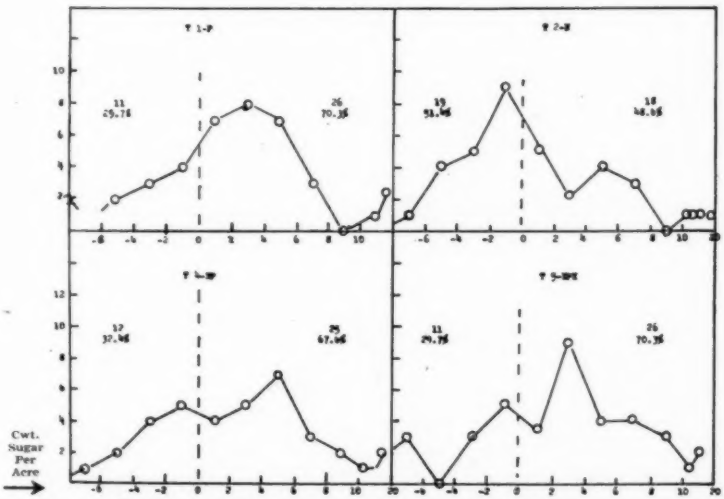


Figure 2.—Frequency distribution curves showing the number and percentage of farms in various sugar yield increase groups for treatments 1, 2, 4 and 5 compared with check 2.

The number and percentage of farms which gave significant response to fertilizers is shown in table 4. Only about 30 percent of the farms gave significant F values for treatments but since the treatments were made only in duplicate, the number responding to treatment is comparatively large. Well-replicated experiments probably would show a much higher percentage.

**Table 4.—Number of separate experiments with significant F values for treatment and replication.**

| Results studied | Treatment | Replication |
|---|---|---|
| Yield beets | 12 | 14 |
| Percent sugar | 11 | 11 |
| Yield sugar | 11 | 10 |

The question frequently has been raised regarding the comparative response to fertilizers of high- and low-yielding fields. Correlation coefficients between yields of the untreated plots (check 2) and the increase in yields due to N, P, and NP were determined. The correlations between yield of the check and N or P were not significant but between the increase of yield due to NP and the yield of the untreated plots, a significant negative correlation of —.386 was found, indicating a tendency for lower response on the high-fertility fields.

*Conclusions.*—On the basis of this experiment there appears to be a large potential source of increased crop yields in northeastern Colorado which might be obtained by the use of fertilizers. This experiment has shown the response from a few of many possible fertilizer combinations on sample farms of the areas, but further research is necessary to provide a means of determining the best fertilizer practices to meet the highly variable needs of the many different farms and the different crops.

## Results for Nebraska

Fourteen fertilizer experiments were conducted in Nebraska. The mean yields of sugar beet, percentage sugar, and gross sugar per acre of these fourteen experiments are presented in table 5. In addition, similar data are presented for the seven fields where noticeable increases in sugar production were obtained from the use of commercial fertilizer and for the seven fields where only small increases or noticeable decreases in sugar production were obtained as a result of the use of commercial fertilizer. None of the fields in the first group of seven received an application of manure in 1947 whereas five of the seven fields in the second group received an application of manure. An attempt was made to group the experiments into two groups according to soil series but the data were not sufficiently homogeneous to warrant such a grouping. Gross sugar production by individual experiments is presented in table 6.

**Table 5.**—Mean increase or decrease in yield due to treatment and yield of check in tons beets, percentage sugar and gross sugar per acre, Nebraska, 1947.

| | Treatment | | | | | | | | | LSD[4] 5-percent point |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 P | 2 N | 3 2(N/2) | 4 NP | 5 NPK | 6 2(NPK) | 7[1] NP | 8[2] 2(N/2)P | 9[3] Ck. | |
| **Mean 14 fields** | | | | | | | | | | |
| Tons beets | 0.95 | 0.63 | 0.83 | 1.43 | 2.07 | 2.29 | 1.72 | 1.58 | 14.83 | 0.48 |
| Percent sugar | 0.13 | —0.48 | —0.54 | —0.65 | —0.55 | —1.05 | —0.30 | —0.48 | 13.2 | 0.21 |
| Pounds sugar | 297 | 28 | 54 | 182 | 405 | 224 | 355 | 268 | 3877 | 150 |
| **Mean 7 fields showing increased production of sugar due to fertilizers** | | | | | | | | | | |
| Tons beets | 2.40 | 1.39 | 1.38 | 2.88 | 3.57 | 3.77 | 3.03 | 2.91 | 11.94 | 0.79 |
| Percent sugar | 0.12 | —0.40 | —0.16 | —0.40 | —0.31 | —0.86 | —0.34 | —0.50 | 13.6 | 0.29 |
| Pounds sugar | 694 | 284 | 370 | 668 | 909 | 758 | 713 | 639 | 3207 | 244 |
| **Mean 7 fields showing slight increases or noticeable decreases in sugar production due to fertilizer** | | | | | | | | | | |
| Tons beets | —0.24 | 0.01 | 0.39 | 0.24 | 0.84 | 1.08 | 0.66 | 0.49 | 17.22 | 0.63 |
| Percent sugar | 0.12 | —0.56 | —0.86 | —0.88 | —0.75 | —1.23 | —0.28 | —0.47 | 12.9 | 0.29 |
| Pounds sugar | —3 | —186 | —210 | —223 | —15 | —222 | 56 | —41 | 4436 | 185 |

[1]Comparable with treatment 4 except N side-dressed at planting time.
[2]Comparable with treatment 4 except ½ N side-dressed at planting time and ½ N side-dressed after thinning.
[3]For description of treatments according to number see table 1.
[4]Least significant difference at 5-percent point (odds 19:1).

*Nitrogen.*—Based on the mean of the fourteen experiments, the application of a nitrogen fertilizer alone had no significant effect upon the production of sugar. This was due to the fact that a significant increase in yield of roots was offset by significant decrease in sugar percentage. However, the mean for the first seven fields shows a significant increase in sugar due to an application of nitrogen fertilizer alone even though the sugar percentage was decreased. On the other hand, a significant decrease in yield of sugar was obtained for the mean of the second seven experiments as a result of an application of nitrogen fertilizer. The time of application of the nitrogen fertilizer had no significant effect upon the production of sugar.

**Table 6.**—Increase or decrease in yield due to treatment and yield of check in pounds gross sugar per acre for individual experiments, Nebraska, 1947.

| Field No. | Treatment | | | | | | | | | LSD[4] 5-percent point |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 P | 2 N | 3 2(N/2) | 4 NP | 5 NPK | 6 2(NPK) | 7[1] NP | 8[2] 2(N/2)P | 9[3] Ck. | |
| **Fields showing increased production of sugar due to fertilizer** | | | | | | | | | | |
| 1 | 294 | —258 | —158 | 312 | 455 | 671 | 536 | 414 | 2111 | 527 |
| 2 | 920 | 439 | 785 | 1192 | 1459 | 1345 | 1446 | 1094 | 2402 | 572 |
| 3 | 702 | —184 | 155 | 940 | 585 | 894 | 768 | 422 | 2887 | 676 |
| 4 | 476 | 60 | 401 | 570 | 1135 | 1002 | 516 | 897 | 2729 | 423 |
| 5 | 706 | 729 | 1335 | 609 | 1428 | 1283 | 974 | 860 | 3425 | 742 |
| 6 | 1123 | 800 | 217 | 717 | 978 | 267 | 669 | 735 | 3832 | 790 |
| 7 | 421 | 144 | —71 | 319 | 293 | 93 | 117 | 6 | 4747 | NS[5] |
| **Fields showing slight increases or noticeable decreases in sugar due to fertilizer** | | | | | | | | | | |
| 8 | —368 | —22 | 111 | 32 | 318 | 63 | 164 | 106 | 2263 | NS |
| 9 | —81 | 123 | —234 | —479 | —234 | —421 | 124 | 114 | 3843 | 407 |
| 10 | —64 | —190 | —202 | —508 | —343 | —691 | —147 | —145 | 4693 | 369 |
| 11 | 255 | —442 | —383 | —428 | —107 | 93 | 173 | —77 | 3927 | NS |
| 12 | 126 | —538 | —558 | 5 | 258 | —215 | —183 | —16 | 5151 | NS |
| 13 | 127 | —407 | —329 | —36 | —1 | —263 | 307 | —273 | 5193 | NS |
| 14 | —84 | —27 | —2 | —270 | —36 | —174 | —153 | —33 | 6137 | NS |

[1]Comparable with treatment 4 except N side-dressed at planting time.
[2]Comparable with treatment 4 except ½ N side-dressed at planting time and ½ N side-dressed after thinning.
[3]For description of treatments according to number see table 1.
[4]Least significant difference at 5-percent point (odds 19:1).
[5]Differences not significant at 5-percent point.

There was considerable variation in the results obtained from the individual experiments, only three experiments showing a significant increase in yield of sugar as the result of an application of a nitrogen fertilizer alone (table 6).

*Phosphate.*—An application of a phosphate fertilizer alone increased sugar production significantly based on either the mean of the fourteen fields or the mean of the first seven fields (table 5). This increased sugar production was due to a significant increase in yield of roots and a small but not significant increase in sugar percentage. The mean of the second seven fields showed no significant effect of the phosphate fertilizer upon sugar production.

The results obtained with phosphate fertilizer alone were not quite as variable in the individual experiments as those obtained with nitrogen alone. Significant increases in production of sugar were obtained in four of the individual experiments.

*Nitrogen + Phosphorus.*—Based on the mean of the fourteen fields or the mean of the first seven fields, a combination of nitrogen and phosphorus fertilizers increased the yield of sugar significantly over the application of a nitrogen fertilizer alone. However, the increases were not significantly greater than those obtained from the application of a phosphate fertilizer alone. On the basis of the mean of the fourteen fields or the mean of the second seven fields, the increases were significantly greater where the nitrogen was applied at planting time than where it was applied following the thinning of the beets. This latter difference was due to a smaller increase in root production as well as to a greater decrease in sugar percentage. In those fields showing a marked response to fertilizer application, there was little difference in yield due to time of application of the nitrogen fertilizer.

A combination of nitrogen and phosphorus fertilizers increased the yield of sugar significantly in five of the individual experiments whereas the yield was decreased significantly in two experiments where the nitrogen was applied following thinning. On the basis of these results and those reported for an application of a nitrogen fertilizer alone, it seems apparent that nitrogen fertilizers should not be indiscriminately applied to lands that have adequate supplies of available nitrogen.

*Nitrogen + phosphorus + potassium.*—On the basis of the mean of fourteen fields, the addition of a potassium fertilizer increased the yields significantly over a similar treatment without potash (table 5, treatments 4 and 5). However, the increases were not significantly greater than where phosphate alone was applied or where a combination of nitrogen and phosphorus fertilizers were applied with the nitrogen being applied at planting time. Where double the rate of fertilizer containing nitrogen, phosphorus and potassium was applied, the increases were less than where the smaller rate was applied. This was due largely to the marked decrease in percentage sugar where the large rate of fertilizer was used.

In two of the individual experiments the application of a potash fertilizer increased the yield of sugar significantly over a similar treatment without potash.

*Conclusions.*—On the basis of the results obtained in Nebraska during 1947, the following conclusions appear to be warranted:

1. Commercial fertilizer can have an important part in the production of sugar by sugar beets.

2. One fertilizer cannot be recommended generally for all fields. In some fields the application of a nitrogen fertilizer alone may give maximum yields, in other fields the application of a phosphate fertilizer alone may produce maximum yields, and in still other fields a combination of the two fertilizers may be necessary to produce maximum yields. Potash fertilizer may be needed in some fields in addition to nitrogen and phosphorus fertilizers.

3. Nitrogen fertilizers should not be used indiscriminately. In general, it appears to be a better practice to apply the nitrogen fertilizer at planting time, especially if the field is likely to be moderately well supplied with available nitrogen. Where marked nitrogen deficiency occurs, a late application would be satisfactory.

## Results for Wyoming

The variation in treatments that existed in the Wyoming tests as compared to those used in Colorado lies in treatment 3. The basic rate of phosphate was used with the split application of nitrogen for it was thought at the time of designing the experiment that phosphate might generally be the limiting element and that one would not have proper expression in growth from the addition of nitrogen unless used with phosphate. Though ammonium sulfate was used in place of ammonium nitrate in northern Wyoming the quantity of nitrogen applied was maintained equivalent and it is felt that no difference should exist from this change in yield responses obtained.

In spite of the intended uniformity in conducting the fertilizer tests a geographical consideration divides the results into two classes. An examination of the data indicates that the location effect is indeed very marked. In view of this difference and the difference between tests within an area the results of each test are presented in tables 7 and 8.

In northern Wyoming (Lovell District) no apparent response was obtained from the use of phosphate alone or in combination with other elements. The general increases on the whole appear attributable to the application of nitrogen. While the application of part of the nitrogen at planting time might be beneficial, there is also indication of possible loss of this element (Hartman field, treatment 3, table 7) when an appreciable portion is applied early.

**Table 7.**—Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in tons beets, percentage sugar and gross sugar per acre for two locations in the Lovell District, 1947.

| | Treatment | | | | | | | | | LSD[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 P | 2 N | 3 2(N/2)P | 4 NP | 5 NPK | 6 2(NPK) | 7 NPK+ | 8 $Ck_1$ | 9[1] $Ck_2$ | 5% point | 1% point |
| **Hartman Farm, Basin, Wyoming** | | | | | | | | | | | |
| Tons beets | 0.05 | 3.94 | 2.45 | 3.31 | 3.43 | 5.80 | 5.05 | 1.00 | 15.11 | 1.92 | 2.66 |
| Percent sugar | 0.05 | 0.23 | 0.58 | 0.08 | 0.13 | 0.13 | —0.44 | 0.88 | 17.29 | .67 | NS[3] |
| Pounds sugar | 32 | 1450 | 1051 | 1174 | 1234 | 2060 | 1569 | 629 | 5225 | 714 | 987 |
| **Kegi Farm, Powell, Wyoming** | | | | | | | | | | | |
| Tons beets | —1.40 | 0.63 | 1.14 | 0.41 | 0.85 | 0.70 | 0.24 | —1.14 | 16.63 | 1.97 | NS |
| Percent sugar | 0.37 | 0.12 | —0.14 | 0.42 | —0.08 | —0.61 | —0.03 | —0.03 | 18.30 | NS | NS |
| Pounds sugar | —400 | 272 | 367 | 293 | 283 | 44 | 77 | —427 | 6087 | NS | NS |

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

**Table 8.**—Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in tons beets, percentage sugar and gross sugar per acre for three locations in the Wheatland District, 1947.

| | Treatment | | | | | | | | | LSD[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 P | 2 N | 3 2(N/2)P | 4 NP | 5 NPK | 6 2(NPK) | 7 NPK+ | 8 $Ck_1$ | 9[1] $Ck_2$ | 5% point | 1% point |
| **Stumpff Farm, Wheatland, Wyoming** | | | | | | | | | | | |
| Tons beets | 4.66 | .07 | 8.36 | 8.88 | 7.17 | 8.01 | 7.92 | 1.86 | 5.03 | 2.50 | 3.64 |
| Percent sugar | 0.6 | —0.4 | —0.9 | —0.3 | —0.4 | —0.4 | —1.4 | —1.0 | 14.6 | NS | NS[3] |
| Pounds sugar | 1472 | —21 | 2205 | 2514 | 1988 | 2226 | 1942 | 410 | 1464 | 793 | 1154 |
| **Dinges Farm, Wheatland, Wyoming** | | | | | | | | | | | |
| Tons beets | 0.75 | 0.18 | 1.31 | 1.72 | 0.70 | 0.88 | 0.64 | 1.44 | 14.05 | 1.34 | NS |
| Percent sugar | 0.3 | —0.2 | 0.0 | —0.3 | —0.1 | —1.7 | —0.2 | 0.5 | 14.9 | .80 | 1.16 |
| Pounds sugar | 312 | —18 | 375 | 418 | 179 | —245 | 117 | 584 | 4187 | 459 | NS |
| **Raines Farm, Wheatland, Wyoming** | | | | | | | | | | | |
| Tons beets | 2.18 | 0.84 | 1.00 | 0.78 | 2.35 | 1.74 | 2.45 | 1.35 | 18.40 | 1.53 | 2.11 |
| Percent sugar | 0.8 | —0.1 | 0.2 | 0.0 | 0.4 | 0.3 | —0.2 | —0.8 | 11.2 | NS | NS |
| Pounds sugar | 817 | 139 | 301 | 174 | 692 | 510 | 465 | —14 | 4122 | 403 | 555 |

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

In the southeastern area of Wyoming (Wheatland District) the tests on three farms (table 8) gave very different results. The results of the single test on the Stumpff farm reveal one of the most striking examples of phosphate deficiency. While nitrogen was also deficient in this field the application of nitrogen alone gave no response, except possibly to hasten the development of phosphate deficiency symptoms, which were very evident in the beets growing on the unphosphated plots. The phosphate application alone gave an increase in yield of approximately 3 tons beets per acre and when nitrogen was added also the increase amounted to about 6.7 tons. Thus, the yield from the NP combination was nearly twice that of check 1 and more than twice that of check 2. The other two fields considered to be of medium-to-high fertility, respectively, did not respond so well to the fertilizer treatment.

## Results for Montana

During 1947, eight fertilizer tests were placed on sugar beets in the Upper Yellowstone Valley of Montana. One test was abandoned because disease was prevalent in all plots, resulting in poor stands. A second test was abandoned because harvesting was interrupted by rain and yields were not comparable on the two harvesting dates. This report deals with the other six tests which consisted of randomized triplicate plots, each six rows wide and at least 500 feet long. The results are given for gross sugar, tons beets and percentage sugar in tables 9, 10 and 11, respectively.

**Table 9.**—Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in pounds gross sugar per acre at six locations, Montana, 1947.

| | Treatment | | | | | | | | | LSD[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | 1 P | 2 N | 3 2(N/2)P | 4 NP | 5 NPK | 6 2(NPK) | 7 NPK+ | 8 $Ck_1$ | 9[1] $Ck_2$ | 5% point | 1% point |
| 1 | —63 | 81 | 190 | —201 | —23 | —99 | 108 | —54 | 4430 | NS[3] | NS |
| 2 | 554 | 480 | 792 | 1606 | 1012 | 1086 | 996 | 376 | 5750 | 630 | 867 |
| 3 | —243 | 1030 | 415 | 398 | 321 | 112 | 410 | —104 | 4363 | 325 | 448 |
| 4 | 275 | —56 | —70 | —301 | 00 | 99 | 209 | 311 | 7687 | NS | NS |
| 5 | 12 | 636 | 204 | 809 | 686 | 1070 | 863 | —98 | 3892 | 470 | 647 |
| 6 | 14 | —176 | —352 | 30 | 149 | 46 | 325 | 112 | 4126 | NS | NS |
| Mean | 92 | 333 | 197 | 390 | 358 | 386 | 485 | 90 | 5041 | 207 | 285 |

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

**Table 10.**—Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in tons beets per acre at six locations, Montana, 1947.

| | Treatment | | | | | | | | | LSD[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | 1 P | 2 N | 3 2(N/2)P | 4 NP | 5 NPK | 6 2(NPK) | 7 NPK+ | 8 $Ck_1$ | 9[1] $Ck_2$ | 5% point | 1% point |
| 1 | —0.06 | 0.64 | 1.25 | —0.41 | 0.89 | 0.89 | 1.46 | 0.20 | 13.80 | NS[3] | NS |
| 2 | 0.88 | 1.82 | 2.49 | 4.69 | 3.07 | 3.38 | 3.17 | 0.49 | 17.36 | 1.84 | 2.54 |
| 3 | —0.77 | 3.27 | 1.39 | 1.43 | 1.10 | 0.78 | 1.36 | 0.04 | 12.50 | 1.88 | 2.60 |
| 4 | 0.05 | —0.35 | —0.33 | —0.75 | 0.34 | 1.10 | 0.52 | 0.05 | 25.42 | NS | NS |
| 5 | 0.07 | 1.85 | 1.10 | 2.42 | 2.44 | 4.06 | 2.69 | —0.42 | 12.58 | 1.44 | 1.92 |
| 6 | —0.31 | —0.09 | —0.65 | 0.64 | 0.80 | 1.20 | 0.99 | 0.16 | 13.70 | NS | NS |
| Mean | 0 | 1.19 | 0.88 | 1.34 | 1.44 | 1.90 | 1.70 | 0.09 | 15.89 | 0.72 | 0.96 |

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

**Table 11.**—Increase or decrease in percentage sugar (from check 2) due to treatment and percentage for check 2 at six locations, Montana, 1947.

| | Treatment | | | | | | | | | LSD[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | 1 P | 2 N | 3 2(N/2)P | 4 NP | 5 NPK | 6 2(NPK) | 7 NPK+ | 8 $Ck_1$ | 9[1] $Ck_2$ | 5% point | 1% point |
| 1 | —0.16 | —0.43 | —0.70 | —0.26 | —1.05 | —1.31 | —1.18 | —0.42 | 16.05 | 0.83 | 1.15 |
| 2 | 0.72 | —0.32 | 0.25 | 0.12 | —0.01 | —0.08 | —0.13 | 0.59 | 16.56 | 0.45 | 0.62 |
| 3 | 0.11 | —0.35 | —0.25 | —0.36 | —0.23 | —0.60 | —0.23 | —0.47 | 17.45 | NS | NS[3] |
| 4 | 0.51 | 0.10 | 0.06 | —0.15 | —0.20 | —0.44 | 0.10 | 0.58 | 15.12 | NS | NS |
| 5 | —0.04 | 0.22 | —0.50 | 0.20 | —0.23 | —0.56 | 0.10 | 0.13 | 15.47 | NS | NS |
| 6 | 0.40 | —0.55 | —0.60 | —0.57 | —0.32 | —1.06 | 0.09 | 0.23 | 15.06 | 0.78 | NS |
| Mean | 0.26 | —0.22 | —0.29 | —0.17 | —0.34 | —0.68 | —0.21 | —0.11 | 15.95 | 0.31 | 0.42 |

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

In interpreting the results, increases above check 2 have been used because it is believed this more nearly indicates the increases due to fertilizers. Table 9 shows that in four of the six tests the yield of gross sugar from the phosphated plot was higher than the check but this did not reach significance at the 5-percent level on any test. For nitrogen alone in single application, differences of significance in yields of gross sugar were obtained at only two of the six locations. At these same two locations the single application of nitrogen was also significantly better than the application of phosphorus alone. A comparison of a single application of nitrogen after thinning versus the split application of the same amount, reveals differences of significance at one location but not as averages of all locations.

A combination of nitrogen and phosphorus gave significant increase in gross sugar yields over check 2 in three cases, in three cases over phosphorus alone, in two cases over the split application of nitrogen, and one case over the single application of nitrogen.

The addition of potash to the combination of nitrogen and phosphorus discussed above, failed to give any difference in favor of potash. The application of twice the quantities of nitrogen, phosphorus and potash failed to give any significant increase in yield of sugar as compared with the basic rate at any location.

In five cases out of six, the addition of the "minor elements" (treatment 7) gave an increase in yield of sugar over treatment 5, but none of these increases were significant at the 5-percent level nor was the 127 pounds increase in the average for all locations significant.

The three tests which showed significant differences in yields of gross sugar also showed similar though not identical differences in yield of beets (tables 9 and 10). In the individual tests, 14 plots differed significantly from their checks (check 2) in gross sugar, but in yields of beets only 11 plots showed comparable differences. The average yield of all plots receiving nitrogen showed that this treatment produced yields of beets that were significantly greater than the average yields of the phosphate-treated plots or either of the checks. The split application of nitrogen showed an increase which was significant only at the 5-percent level, while all other plots receiving nitrogen gave highly significant increases. When the yield is expressed in terms of gross sugar per acre, the increase due to a split application of nitrogen did not reach significance, while all other plots receiving nitrogen gave increases which were highly significant.

The percentage sugar in the beets for the different tests varied between 14.00 and 17.56 percent. In only three tests (table 11) did one or more plots differ significantly from the checks and these do not show a definite pattern. In the averages, all plots receiving nitrogen had lower sugar contents than the checks and in two of the six cases this reached the level of significance. The average percentage sugar for the plots receiving phosphate alone showed highly significant increases over all nitrogen-treated plots.

Location 3 had a low yield and a high content of sugar while location 4 had a high yield and a low content of sugar, but location 2 was relatively high in both yield and sugar content.

While fertilizer treatments have given positive yield increases in some of the tests, the treatments used in 1947 did not always correct low yields.

## General Discussion

From the tests reported here it becomes clear that the increased production obtained from the use of commercial fertilizers, and the efficient consumption of available fertilizer supplies, for any one year, lies in the proper distribution and use of that fertilizer. The farms on which fertilizer tests were made did not give 100-percent response or approach closely that percentage. It is realized that measuring yield responses in any one year is not to be taken as an absolute value contributable by the fertilizer. Assuming that the cost of fertilizers added may be paid in different increments per year for a number of years, which may well vary with field, year, and a number of other factors, it is conceivable that at some time hence each field may actually pay manyfold for the fertilizer applied. Yet, in the interests of an investment made each time fertilizers are used, and in the immediate returns that investment can rightfully be expected to give, some conclusions, even though temporary and vulnerable, should be made. These conclusions are:

1. As a side-dressing application, 1000 pounds of fertilizer, or more, as used in treatment 6 is excessive for general practice.

2. The indiscriminate use of nitrogen fertilizer with regard to fields, even at moderate rates, rapidly minimized through reduction in sugar percentage the effectiveness of certain moderate gains made in yield of roots.

3. The results indicate that with some consideration given nitrogen applications in regard to fields, increases in gross sugar production from the use of nitrogen on the sugar beet crop could be improved.

4. The response in certain fields from phosphate gave evidence that fertilizers containing this element are needed. More knowledge on when and how to use phosphate might well increase the efficiency of its use.

5. Nitrogen and phosphate, being the two most frequent deficiencies and often occurring on the same fields, make, on a probability basis, a combined application of both nitrogen and phosphate the most reliable when little or no information on the field is available.

6. The possible need for potassium was suggested in the results of two tests in Nebraska and a similar number in Colorado. This gives indication that on certain farms the supply of potassium in the soil has dropped below the critical level necessary for high yields.

7. The minor elements, Fe, Mn, Cu, Zn and B gave no beneficial response in yield or sugar percentage under the conditions of the tests

conducted in Colorado and Wyoming. A beneficial effect from at least one of the mentioned minor elements was suggested in five of the six tests conducted in Montana.

8. No general difference in response was noted between time of nitrogen application for the alternatives: all at planting time, one-half at planting time and one-half at thinning time, or all at thinning time.

9. The side-dressing equipment itself may do damage to the extent that it becomes a factor important to yield.

# Summary of Fertilizer Results, 1947

A. R. Downie[1]

ABSTRACT: The wide variety of soil types and climatological differences in the beet-growing areas of the American Crystal Sugar Company make for a considerable variation in fertilizer practices. Accordingly, the results of the commercial-fertilizer tests are summarized by the different growing areas.

*California*

Of three fertilizer tests conducted in this area, only one gave significant differences. However, the tendency for high nitrogen applications to depress sucrose percentages was evident in all tests. The sucrose percentage of 11-48-0 was significantly higher than the two treatments with the highest nitrogen content. However, there were no significant differences between treatments in yield of pounds sugar per acre.

*Arkansas Valley, Colorado*

The complete fertilizer 10-43-6 resulted in the highest pounds sugar-per-acre yield in this area. It was significantly better than the check and the ammonium nitrate treatments. Ammophos (11-48-0) gave a significantly higher sugar-per-acre yield than ammonium nitrate.

*Northern Iowa-Southern Minnesota*

In the five tests in this area 4-24-4 fertilizer had the highest yields in tonnage and sugar per acre.

*Red River Valley, Minnesota*

All fertilizers tested in this area resulted in significantly higher tonnage yields but only treble-superphosphate gave a significant increase over the check in pounds sugar per acre.

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THE WIDE VARIETY of soil types and climatological differences in the growing areas of the American Crystal Sugar Company make for a considerable variation in commercial fertilizer responses. This situation makes it mandatory that fertilizer tests be designed with the needs, as indicated from previous testing, of the particular growing area in mind. Accordingly, the fertilizer tests conducted in 1947 are summarized for the area in which the tests were carried out.

## Tests in the California Area

The general fertilizer practice in this area is to apply liberal applications of nitrogenous fertilizers at the time of seedbed preparation, by side-dressing shortly after thinning, or by a combination of the two methods.

[1]Plant Pathologist, American Crystal Sugar Company, Rocky Ford, Colorado.

Over a period of years, this practice has usually resulted in increased tonnages but in the last few years it has very often resulted in decreased sugar content of the beets.

Three replicated plot tests were run in this area. Each test consisted of eight fertilizer combinations replicated four times, in plots 100 feet long by four rows wide. The fertilizers were applied immediately before planting. There were two tests in the San Joaquin Valley and one test near Clarksburg. The fertilizers used, the rates per acre, yield of beets, percentage sucrose, and sugar-per-acre yields are summarized for the tests in table 1. The results for both the tests in the San Joaquin Valley are combined.

Curly top played an important role in the low tonnages obtained in these San Joaquin Valley tests. Under the conditions of these two experiments, there were no significant differences among the fertilizer treatments.

Because of missing plots, the 37.5-pound rate of nitrogen and the combination of 37.5 pounds of nitrogen with the 60-pound rate of 11-48-0 are not included in the data for the Clarksburg test. However, significant differences in tonnage yield and in percentage sucrose were obtained in this test. The 120-pound rate of 17-7-0 and this same fertilizer combined with the light and heavier rate of ammonium sulphate resulted in significantly better tonnage yields than the unfertilized check. Also the heavy rate of nitrogen plus 17-7-0 was better than the 75-pound rate of nitrogen alone. Whether this increase in yield was due entirely to an increase in total nitrogen, or whether phosphate played a role cannot be determined from this experiment, but it is worthy of further investigation.

There is a general trend at both locations for the sucrose to be depressed as the units of nitrogen applied are increased. The 11-48-0 fertilizer in the Clarksburg test resulted in a significantly higher sucrose percentage than the two fertilizer treatments which contained the highest amounts of nitrogen. This is in line with the findings of Pendleton and Robbins (2)[2] in the application of nitrogen on fairly high fertility fields.

### Arkansas Valley, Colorado Area

The results of previous testing has indicated the need for a high phosphate fertilizer in this area. A lesser response is obtained with nitrogenous fertilizers, depending to a large extent on rotational practices and on the use of barnyard manure. According to Skuderna (3) the requirement of potash in the fertilizer mixture may be necessary on the very light textured soils, but not required in the heavier textured soils which are usually higher in organic matter.

Six fertilizer strip tests were carried out in this area in 1947. Each test consisted of five fertilizer treatments run in duplicate on each of six farms. The plots were twelve rows wide and ran the entire length of the field, usually being ½ to 1 acre in size. Three samples of 20 beets each

[2]Numbers in parentheses refer to literature cited.

**Table 1.—Results of fertilizer experiments in the California area, 1947.**

| Fertilizers | Rate per acre Units of plant food | San Joaquin Valley | | | Clarksburg | | |
|---|---|---|---|---|---|---|---|
| | | Tons per acre | Percentage sucrose | Pounds sugar per acre | Tons per acre | Percentage sucrose | Pounds sugar per acre |
| 20.5-0-0 | 37.5 | 14.01 | 15.08 | 4225 | | | |
| 20.5-0-0 | 75 | 13.05 | 15.24 | 3977 | 27.80 | 18.10 | 10,063 |
| 20.5-0-0 + 17-7-0 | 37.5 + 60 | 14.14 | 15.24 | 4309 | 29.92 | 18.05 | 10,796 |
| 20.5-0-0 + 17-7-0 | 75 + 60 | 14.82 | 15.02 | 4451 | 31.19 | 17.68 | 11,035 |
| 20.5-0-0 + 11-48-0 | 37.5 + 60 | 14.75 | 14.93 | 4404 | | | |
| 20.5-0-0 + 11-48-0 | 75 + 60 | 13.03 | 14.61 | 3807 | 27.16 | 17.89 | 9,727 |
| 17-7-0 | 120 | 13.78 | 14.33 | 3959 | 28.84 | 18.00 | 10,390 |
| 11-48-0 | 120 | 12.80 | 15.09 | 3863 | 27.89 | 19.59 | 10,927 |
| 0-0-0 | -- | 11.58 | 15.50 | 3589 | 24.65 | 19.12 | 9,428 |
| Difference required for significance | | NS | NS | NS | 3.37 | 1.61 | NS |

were selected at harvest for sugar analysis. All of the beets from the twelve row strips were hauled to the beet dump and weighed. The results of the six tests and the kinds and amounts of fertilizer applied are presented in table 2.

**Table 2.**—Average results of duplicate strip tests on six farms in the Arkansas Valley, Colorado, 1947.

| Fertilizer | Rate in pounds Plant food per acre | Yield in tons per acre | Percentage sucrose | Pounds sugar per acre |
|---|---|---|---|---|
| 32.5-0-0 | 65 | 13.32 | 14.15 | 3787 |
| 0-43-0 | 106 | 15.42 | 15.25 | 4403 |
| 11-48-0 | 106 | 16.60 | 14.46 | 4826 |
| 10-43-6 | 106 | 16.56 | 14.60 | 4938 |
| 0-0-0 | — | 13.70 | 14.99 | 4117 |
| Difference required for significance | | .99 | .55 | 779 |

The three high phosphate fertilizers were all significantly higher in tonnage than the unfertilized check and the ammonium nitrate treatment. Also, the ammonium nitrate application had a significantly lower sucrose content than the unfertilized check while the treble-superphosphate was significantly higher in sucrose content than the other three fertilizers used in the tests. However, in pounds sugar-per-acre yields, 10-43-8 was significantly higher than the check and the ammonium nitrate, while 11-48-0 was significantly better than the ammonium nitrate but not better than the check.

These results indicate that there is need for additional investigation on the use of potash in this area.

### Northern Iowa-Southern Minnesota Area

Superphosphate and such mixtures as 2-12-6, 0-12-12, and other low analysis fertilizers were commonly used in this area up until the past few years. In recent years there has been available 0-43-0 and higher analysis complete fertilizers. The use of these latter fertilizers in sugar beet farming has resulted in more satisfactory responses since there is the tendency to apply more plant food than formerly was done.

A total of five tests were made in this area. The tests were duplicated strips of four fertilizers and the unfertilized check. Three of the tests were made with one group of fertilizers and the other two tests were made with a different group. Since there were different fertilizers compared in each group all five tests cannot be averaged; therefore, table 3 gives the results of the fertilizers on yields, sucrose and sugar per acre for each group.

The results from all five tests reveal that the complete fertilizer 4-24-4 resulted in the highest tonnages and pounds sugar per acre. This is fairly well in agreement with results obtained the previous year[1] when 2-12-6 and 4-24-4 fertilizers gave the highest yields.

**Table 3.** Results of fertilizer tests in the northern Iowa-southern Minnesota area.

| Fertilizer | Rate per acre Units of plant food | Number ½ acre strips used to obtain averages | Tons per acre | Percentage sucrose | Pounds sugar per acre |
|---|---|---|---|---|---|
| | | Group 1 | | | |
| 32.5-0-0 | 40 | 6 | 7.27 | 16.1 | 2241 |
| 0-43-0 | 86 | 6 | 8.35 | 16.4 | 2738 |
| 8-32-0 | 86 | 6 | 8.19 | 16.2 | 2653 |
| 4-24-4 | 71 | 6 | 8.80 | 16.8 | 2957 |
| 0-0-0 | -- | 6 | 6.90 | 16.4 | 2263 |
| | | Group 2 | | | |
| 20.5-0-0 | 40 | 4 | 9.44 | 16.51 | 3117 |
| 10-20-0 | 80 | 4 | 9.56 | 16.71 | 3195 |
| 11-48-0 | 94 | 4 | 9.43 | 16.84 | 3176 |
| 4-24-4 | 80 | 4 | 10.76 | 17.25 | 3712 |
| 0-0-0 | -- | 4 | 9.21 | 17.52 | 3221 |

## Red River Valley, Minnesota

The common practice in this area is for beets to follow sweetclover-summer fallow. In addition, the soil type over the entire area is much more uniform than any of the other beet-growing areas in the territories served by the American Crystal Sugar Company. These conditions make it more nearly possible to make general recommendations as to commercial fertilizer practices.

Four tests were conducted in this area. Each test consisted of four fertilizer treatments and an unfertilized check, replicated twice in eight-row strips in four different fields. The results from all four fields were analyzed as a randomized block of eight replications. Table 4 presents the kinds and rates of fertilizers per acre, the tonnage yield, percentage sucrose, and pounds sugar per acre.

**Table 4.**—Combined results of fertilizer strip tests on four farms in the Red River Valley, Minnesota, 1947.

| Fertilizer | Rate in pounds plant food per acre | Tons beets per acre | Percentage sucrose | Pounds sugar per acre |
|---|---|---|---|---|
| 4-24-12 | 64 | 9.89 | 15.62 | 3028 |
| 0-24-12 | 65 | 10.20 | 15.24 | 3051 |
| 0-36-8 | 66 | 10.02 | 15.21 | 3002 |
| 0-43-0 | 65 | 10.90 | 15.24 | 3270 |
| 0-0-0 | -- | 8.77 | 15.78 | 2682 |
| Difference required for significance | | .95 | .49 | 379 |

The tests in this area resulted in significant increases in tonnage yield from all four fertilizers over the unfertilized strips; however, three of the fertilizers caused a significant decrease in the sugar content of the beets. The reduction in sucrose content is further reflected in the sugar-per-acre yield since only the treble-superphosphate gave a significant increase over the unfertilized check.

These results emphasize that a high phosphate fertilizer is the requirement for this area; however, over a period of years it has usually been profitable to include some potash with the phosphate. The fertilizer mixture 0-36-8 has performed very well, comparing very favorably with treble-superphosphate in most years.

**Summary**

Fertilizer tests were conducted in some of the beet-growing areas of the American Crystal Sugar Company.

The tests in the San Joaquin Valley and at Clarksburg, California, resulted in increased tonnages by the use of high nitrogen fertilizer; however, in the Clarksburg test the sucrose percentages were reduced enough so that there was no significant differences in pounds sugar per acre.

Experiments on soils in the Arkansas Valley, Colorado, definitely demonstrated the need for a high analysis phosphate fertilizer. Applications of the 106 units of plant food in the form of 0-43-0, 11-48-0, and 10-43-6 significantly outyielded the unfertilized treatment, and the 65-pound application of nitrogen. However, the treble-superphosphate had a significantly higher sucrose percentage than did the other three fertilizers; and the 10-43-6 and 11-48-0 fertilizers gave significant differences in sugar-per-acre yields over the ammonium nitrate but only the 10-43-6 treatment was significantly better than the unfertilized treatment in this capacity.

Highest yields per acre in the Northern Iowa-Southern Minnesota area were obtained with the complete fertilizer 4-24-4.

All four fertilizers tested in the Red River Valley of Minnesota resulted in significantly higher yields than the unfertilized treatment. However, only treble-superphosphate was significantly higher than the check in pounds sugar-per-acre yield.

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# The Effect of Phosphate Fertilizer on Yield of Sugar Beets[1]

F. J. Hills[2] and R. G. Veaco[2]

Because of the lack of positive experimental evidence on the response of sugar beets to phosphate fertilizer in the Sacramento and San Joaquin Valleys of California, a series of experiments were undertaken during the 1947 crop season to ascertain the effectiveness of phosphate in increasing yields of sugar per acre.

Twelve separate trials were made—six were located in the San Joaquin Valley in Kern County and six in the lower Sacramento Valley. Each trial was conducted on a different major soil type on which sugar beets are grown in the areas concerned.

The experiments were located in fields which had not been fertilized with phosphate for at least the 2 previous years.

*Methods and Procedure.*—Each trial consisted of eight plots—four treated and four untreated. The plots were paired and the pairs laid end to end down the rows. A plot was four rows wide by 100 feet long. Alternate numbers of each pair of plots were treated so that the treatments occurred in a checkerboard arrangement.

The treatment was constant for each trial, but consisted of from 157 to 221 pounds of $P_2O_5$ per acre, depending upon the row spacing of the trial concerned. Single superphosphate was banded from 4 to 6 inches from the plants in the center two rows. The time of application varied among trials from just prior to planting to thinning time.

On the six trials in Kern County, petiole samples were taken from each plot at 4-week intervals and analyzed[3] to determine whether the treatment had been effective in increasing the phosphate intake of the plants and if a response was indicated by early low phosphate values.

Each trial, treatment and control alike, received nitrogen fertilizer of the type and amount that each grower applied to his field.

Eighty feet of the center two rows of each plot were harvested.

*Results.*—There was no visible response to the treatment in any trial at any stage of growth. The yield data are tabulated in table 1. Data are presented for eleven trials only as circumstances prevented harvest of the twelfth.

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[1]Conducted by the Spreckels Sugar Company in cooperation with Dr. Albert Ulrich of the Division of Plant Nutrition, University of California, and the Extension Service of Kern County, California.

[2]Spreckels Sugar Company.

[3]All petiole analyses were made by the Division of Plant Nutrition, University of California.

**Table 1.**—Summary of yield data, 1947 phosphate trials. Each value is the mean of four replications.

| | Trial number and soil type | Treatment | Tons Beets per acre | Difference in tons beets per acre | Percent sugar | Difference in sugar percent | Tons sugar per acre | Difference in tons sugar per acre |
|---|---|---|---|---|---|---|---|---|
| 1. | Exeter sandy loam | P[1] | 21.21 | +.59 | 14.17 | —1.13 | 3.003 | —.133 |
| | | O | 20.62 | | 15.30 | | 3.136 | |
| | Difference required for significance (19:1) | | | 4.13 | | .49 | | .55 |
| 2. | Delano loamy sand | P | 33.91 | +1.19 | 12.52 | +.02 | 4.247 | +.159 |
| | | O | 32.72 | | 12.50 | | 4.088 | |
| | Difference required for significance (19:1) | | | 2.86 | | .39 | | .42 |
| 3. | Hesperia sandy loam | P | 31.89 | +.31 | 14.26 | —.04 | 4.705 | +.237 |
| | | O | 31.58 | | 14.30 | | 4.468 | |
| | Difference required for significance (19:1) | | | 7.89 | | 2.44 | | .80 |
| 4. | Traver fine sandy loam | P | 33.72 | —1.04 | 12.88 | —.69 | 4.354 | —.372 |
| | | O | 34.76 | | 13.57 | | 4.726 | |
| | Difference required for significance (19:1) | | | 2.13 | | 2.41 | | .78 |
| 5. | Sacramento clay | P | 20.54 | —3.15 | 12.70 | —.28 | 2.588 | —.545 |
| | | O | 23.69 | | 12.42 | | 3.133 | |
| | Difference required for significance (19:1) | | | 2.73 | | 1.06 | | .34 |
| 6. | San Emigdio fine sandy loam | P | 6.90 | +1.67 | 14.00 | —.68 | .988 | +.206 |
| | | O | 5.23 | | 14.68 | | .782 | |
| | Difference required for significance (19:1) | | | 1.24 | | 1.68 | | .29 |
| 7. | Yolo clay loam | P | 5.75 | —.20 | 14.10 | +1.04 | .812 | +.049 |
| | | O | 5.95 | | 13.06 | | .763 | |
| | Difference required for significance (19:1) | | | 5.08 | | 4.89 | | .48 |
| 8. | Yolo clay | P | 15.37 | +.31 | 11.75 | —.92 | 1.814 | —.103 |
| | | O | 15.06 | | 12.67 | | 1.917 | |
| | Difference required for significance (19:1) | | | .86 | | 3.35 | | .70 |
| 9. | Yolo loam | P | 13.76 | —1.07 | 16.41 | —.20 | 2.258 | —.198 |
| | | O | 14.83 | | 16.61 | | 2.456 | |
| | Difference required for significance (19:1) | | | 2.29 | | 2.81 | | 2.73 |
| 10. | Sacramento clay | P | 24.00 | —.97 | 17.34 | —.54 | 4.135 | —.048 |
| | | O | 23.03 | | 17.88 | | 4.087 | |
| | Difference required for significance (19:1) | | | 7.16 | | .72 | | 1.21 |
| 11. | Columbia clay loam | P | 14.77 | .55 | 20.13 | +.81 | 2.973 | +.013 |
| | | O | 15.32 | | 19.32 | | 2.960 | |
| | Difference required for significance (19:1) | | | 2.11 | | .75 | | .367 |

[1]P=phosphate; O=control.

The yield data on trial 6 indicate a response to the treatment in tons of beets per acre. However, the increase is not significant in sugar per acre. It is felt that the yields from these plots were too greatly affected by curly top to afford conclusive evidence. In this trial there is a good correlation between yield and the number of beets harvested per plot. This, plus the fact that petiole analyses show no indication of a phosphate deficiency, leads to doubt of the significance of the response pending the result of further trials in this area.

No entirely satisfactory explanation can be offered for the significant decrease in yield in the phosphate treatment of trial 5. This may have been due to the fact that in three of the four replications from 30 to 50 more beets were harvested from the paired treated plots. There was no apparent reason for the population differences at harvest time other than the possible failure in obtaining comparable thinned stands.

The significant decrease in sugar percentage in trial 1 and the significant increase in sugar percentage in trial 11 do not amount to much in a practical way as the differences were not enough to significantly effect the yields of sugar per acre.

Petiole analyses on trials 1 through 6 show that the beets in the treated plots initially received greater amounts of $PO_4$ than the control plots; but the $PO_4$ levels in the control plots, with the exception of trial 2, never reached the critical level as defined by Ulrich[4]. In trial 2, the $PO_4$ concentration in the petioles from three of the four control plots reached the critical level sometime during the last month of growth. The deficiency was not of sufficient duration to be noted in yield response. Had the beets been allowed to grow for a longer period, a response may have been noted. It is clear that this area should be watched for possible future response to phosphate fertilization. The petiole analyses data for trial 2 are presented in table 2.

**Table 2.**—Phosphate concentration in sugar beet petioles from trial 2.
Critical level=600-800 ppm.
Expressed in ppm. of $PO_4$—P (dry basis)

| Replication number | Treatment | Date Sampling | | | |
|---|---|---|---|---|---|
| | | March 4 | April 28 | June 25 | July 18[2] |
| 1 | P[1] | 2750 | 3610 | 2280 | 1180 |
| | O | 2100 | 2340 | 2440 | 520 |
| 2 | P | 2980 | 3000 | 2480 | 1150 |
| | O | 1717 | 2240 | 1500 | 850 |
| 3 | P | 3310 | 3420 | 2530 | 1330 |
| | O | 2620 | 2330 | 2210 | 730 |
| 4 | P | 2770 | 3260 | 2780 | 1630 |
| | O | 1460 | 2740 | 2480 | 1170 |

[1]P=plot fertilized with superphosphate; O=control.
[2]Harvest date.

## Summary

1. Twelve experiments were conducted, each on a different soil, to determine if sugar beets would respond to phosphate fertilization.

2. Yield data did not indicate a definite response to phosphate in any of the trials.

[4]See paper by Albert Ulrich, "Plant analysis as a guide to the nutrition of sugar beets in California," on page 364 of these Proceedings.

# Weed Control

# Results With Pre-Emergence Spraying in Beet Field for Control of Wild Oats

R. T. Nelson[1]

Wild oat is a characteristic weed of a large part of the United States. Its occurrence is not peculiar to grain fields, for it occurs and takes its toll of losses in cultivated crops as well. In this connection volunteer domestic small grains can be equally injurious. The monocotyledonous plants, of which the above are members, are generally more resistant to herbicidal sprays than the dicotyledonous plants. This character has delayed the discovery of a good selective spray for the control of weeds in the culture of sugar beets.

In the absence of a selective spray it is necessary to make use of what other differentiating characters exist between weeds and beets. One of the characters employed has been the differential in the date of emergence. This can be used to advantage providing the weeds emerge first and provided there are herbicides available which are effective against the weeds without leaving a toxic residual affecting the beets. Chemicals showing promise in this regard are being tested.

In the spring of 1947 one test with 11 treatments and 4 replications was superimposed on a beet field near Longmont, Colorado. The field had been plowed during the spring and was planted to beets April 11. Flat-bed planting to a depth of 1½ inches had been used. Observations made subsequent to planting but before the beets had emerged revealed that portions of the field were turning green as a result of an abundant growth of wild oats. Plots, 2 rows wide and 65 feet long, were laid out on the field and various sprays were applied to the plots with a knapsack sprayer April 26. The sprayer was equipped with a flat spray nozzle and the applications were made as uniform as possible with a minimum of spray drift.

On May 7 stand counts of beets and weeds were taken on all plots. Pre-thinning beet counts per 100 feet of row, and weed (wild oats) populations in percentage of check as calculated from counts on five 1-square-foot areas per plot for the various sprays employed, are given in table 1.

All the sprays used gave partial control as is indicated by the results in table 1, and in only one case was the stand of beets significantly reduced. In addition to a reduction in the number of weeds, the sprays slowed the growth of those plants that did survive. This difference may be observed in figure 1.

[1]Agronomist, The Great Western Sugar Company Experiment Station, Longmont, Colorado.

**Table 1.—Stand counts of beets for 100 feet of row and wild-oat populations in percentage of check for various pre-emergence spray treatments.**

| Treatment | Beets per 100 feet of row | Wild-oat count in percentage of check |
|---|---|---|
| 1. 50 gallons per acre of standard diesel fuel oil (No. 23-M) gravity 31.3 | 319 | 24 |
| 2. 50 gallon per acre of 1 part oil as above plus 4 parts water (no emulifier) | 288 | 67 |
| 3. Same as No. 2 plus 1 percent sulfur by weight plus emulsifier | 244 | 52 |
| 4. Same as No. 2 plus 1 percent pentachlorophenol by weight plus emulsifier | 233 | 46 |
| 5. 50 gallons per acre of stove oil (No. 1 domestic fuel oil) gravity 35+ | 285 | 32 |
| 6. 50 gallons per acre of kerosene distillate, gravity 35+ | 302 | 47 |
| 7. 30 gallons per acre of diesel fuel oil, gravity 32+, plus 1 quart Sinox[1] | 262 | 42 |
| 8. 100 gallons per acre of 1 part oil as in No. 7 plus 9 parts water plus 1 quart Sinox plus emulsifier | 259 | 50 |
| 9. 100 gallons per acre of 1 part oil as in No. 7 plus 1 part water plus 1 quart Sinox plus emulsifier | 159 | 36 |
| 10. 50 gallons per acre of water containing 3-percent Dow Contact[2] | 235 | 54 |
| 11. Check | 320 | 100 |
| LSD 5-percent point | 103 | 39 |
| LSD 1-percent point | 139 | 41 |

[1]Active ingredient 30-percent sodium dinitro-ortho-cresylate; product of Standard Agricultural Chemicals, Inc.
[2]Active ingredient dinitro secondary butylphenol; product of Dow Chemical Company.

Figure 1.—Pictured in foreground are two 2-row plots; on the left is the check and on the right treatment 1. In the background is pictured the mass of weeds left in the row where unsprayed areas had been cultivated.

Even though the plots needed weeding and cultivating to remove the remaining wild-oat plants and weeds that emerged subsequent to spraying the experiences of this test were very encouraging. Earlier treatment might have given a more complete control.

The straight diesel oil with the low gravity appeared to be the best weed-killer. This would be expected since the low-gravity oils generally contain more unsaturated compounds which are favorable components of petroleum herbicides.

Foul growth, such as wild oats and volunteer small grain, frequently cause an abandoning of beet fields in this area. The results of the test reported here, together with the results on the use of diesel oil for the control of barley[2] suggest that pre-emergence spraying might be a means of cutting down losses in beet acreage due to these weeds. Just how frequently pre-emergence spraying can be used in this area without delayed planting remains to be determined.

[2]Anonymous. Can We Plant Beets in Foul Fields? Through The Leaves. (Great Western Sugar Company Bimonthly Pub.) 24 (5): 8-15. 1947.

# Progress Report on Weed Control Studies at Fort Collins, Colorado[1]

G. W. Deming[2]

The trend toward complete mechanization of the field work of growing the sugar beet crop has focused the attention of the industry on the problems of early season control of weeds in the crop. A weedy initial stand of sugar beets can be cleaned up by hand work to obtain a satisfactory thinned stand that will be relatively weed-free for the balance of the season and will produce a normal crop. With customary practices and equipment it is much more difficult, if not impossible, to achieve such results by machine work alone, if initial stands are weedy.

In two of the 1947 projects of the Sugar-Beet Field Station at Fort Collins,[3] several chemical or cultural methods were tried for the control of weeds in initial stands of sugar beets. The first of these projects was a replicated test of several treatments that might promote better emergence of the sugar beet seedlings and/or control weeds in the initial stands. In the second project, newly discovered chemicals that are important as weed toxicants were applied to the soil. 2,4-Dichlorophenoxyacetic acid (2,4-D) and Isopropyl-N-Phenyl-Carbamate (IPPC) in sand were sprinkled in dry condition on the soil, following basic experiments conducted at Beltsville, Md.[4] Sugar beets were then seeded at intervals after the chemicals had been lightly worked into the surface layer.

The first of these tests was carried to harvest and yield data were obtained. The second test was started somewhat late in the season and only general observations on weed growth and emergence of sugar beet seedlings were recorded.

## Emergence and Weed-control Experiment

This test consisted of 8 randomized blocks of 12 treatments. The plots were 4 rows wide and 50 feet in length with rows 20 inches wide and plant spacing in the row of approximately 12 inches. The two inside rows of each plot were harvested for yields. Two 20-beet samples were taken for analysis and the cleaned weight of all roots obtained for calculation of yields.

The treatments included in this test were as follows:

1. Check: no special treatment.

[1]Scientific Series Paper No. 258. Colorado Agricultural Experiment Station.

[2]Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[3]Investigations of the Division of Sugar Plant Investigations at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado Agricultural Experiment Station and the experiments reported in this paper were conducted on the Agronomy Farm of the latter agency.

[4]Mitchell, John W., and Marth, Paul C., "sensitivity of grasses and some crop plants to Isopropyl-N-Phenyl-Carbamate" Science 106: 15-17, 1947.

2. Ridge cover: a separate cultural operation immediately after planting in which all the space between the rows was given a shallow cultivation and about 1½ to 2 inches of additional soil was thrown on the beet row as a ridge. The ridges were removed 4 to 5 days later.
3. Blade weeder: a flat, blade weeder was run at a depth of 1 inch immediately ahead of the drill shoe of the planter.
4 to 7. Mulches: narrow bands of four mulching materials were spread, very lightly, on the beet rows immediately after planting. The purpose of the mulches was control of soil crust and possible conservation of moisture in the row.
8. Salt: a side-dressing of 500 pounds per acre, applied after thinning, to test possible accessory fertilizer value of salt.
9. IPPC: 5 pounds per acre of the chemical applied as spray for weed control, to the beet rows prior to thinning.
10. Salt: a solution of about 2½ pounds of salt per gallon of water was applied as spray for weed control on the beet rows at the rate of 90 gallons per acre. Applied before thinning.
11. Sodium nitrate: applied as spray for weed control at same rate as for treatment 10.
12. "Fertidene": an organic iodine compound, applied with sprinkling can immediately after planting at rate of 1 gram in 10 quarts of water per 100 feet of row. Purpose was to test possible growth-promoting effect of the chemical.

The soil in the experimental field is Fort Collins Clay loam. In 1946, spring wheat was seeded late on this field and was more weedy than is usual for grain crops. The wheat stubble was irrigated, manured at a moderately heavy rate and fall plowed. Some early germinating weeds such as (*Kochia scoparia* L. Roth), Russian thistle (*Salsola pestifer* A. Nels.) and lambquarter (*Chenopodium album* L.) emerged in late March and early April. Foxtail grass (*Setaria* spp.) was emerging when seedbed preparation was started in mid-April. Because of wet soil the preparation of the seedbed was not completed till April 21. The test was planted May 5 with a four-row tractor drill. Sheared, commercial, sugar beet was planted at the rate of 4½ pounds per acre. In a standard germination test of a sample of this seed, 400 seed pieces produced 438 sprouts from 283 viable seed pieces.

At the time of planting very few weeds were in evidence, but germinating weeds could be found in the soil. Surface moisture had been depleted at this time and very few of the beet seeds were placed in contact with moist soil. A few beet seedlings had emerged by May 13, but the majority emerged in the period May 16 to 20, following showers that began May 9. Showery conditions continued to the end of May at which time moderate to heavy stands of weeds were present on all areas of the test except the plots of treatment 2 and in the rows of treatment 3.

On June 4 and 5 all plots of the test, except those of treatments 9, 10 and 11, were cultivated by hand with Planet Jr. garden cultivators. Weed growth was sufficient to make this job difficult, but a good kill of the weeds between the rows was obtained. The sprays were applied to treatments 9, 10 and 11 on June 5 and 6. Complete first cultivation of the test with a tractor was delayed by weather conditions until June 16. The tools used for the tractor cultivation were knives run close to the rows with duckfeet in the middles. By this time weed growth on the sprayed plots was so dense and vigorous that a good job was impossible and the middles of these rows were finally cleaned by hand hoeing on June 23. In general, cultural operations to mid-June were not timely because of weather conditions. Heavy weed growth had been favored. The test was blocked and thinned by hand on June 24 and 25. Reasonably good and clean-thinned stands were obtained on all plots of the test. Summaries of the counts of initial and thinned stands are given in table 1.

**Table 1.**—Emergence and weed-control experiment, Fort Collins, Colorado, 1947. Summary of initial and thinned stands of sugar beet plants.

| Treatment | Stands[1] | |
|---|---|---|
| | Initial (seedlings per 100 feet of row) | Thinned (plants per 100 feet of row) |
| 1. Check: no treatment | 346 | 91.4 |
| 2. Ridge cover | 367 | 96.5 |
| 3. Blade ahead of drill | 346 | 96.2 |
| 4. Mulch: powdered alfalfa | 340 | 89.6 |
| 5. Mulch: chopped alfalfa | 329 | 87.2 |
| 6. Mulch: rotted manure | 339 | 88.2 |
| 7. Mulch: fresh manure | 343 | 91.2 |
| 8. Salt: side dress after thinning | 334 | 91.5 |
| 9. IPPC: spray before thinning | 359 | 92.6 |
| 10. Salt: spray before thinning | 341 | 91.0 |
| 11. $N_aNO_3$: spray before thinning | 350 | 83.6 |
| 12. "Fertidene": at planting | 349 | 88.9 |

[1]Initial stands given as 4-plot averages. Thinned stands given as 8-plot averages.

Treatments 8 and 12 are not of interest in the present discussion and may be dismissed with the comment that their yields did not significantly differ from the yields of the check. Since the mulches, treatments 4 to 7, inclusive, appear to have had no effect on germination of beet seed, as indicated by the initial stands, under the conditions of this test they may be similarly dismissed.

It appears doubtful that any of the treatments appreciably affected germination of the beet seed or emergence of the beet seedlings. Similarly there is little evidence that the thinned stands were affected by any of the treatments. Treatment 11, which received the sodium nitrate spray, is a possible exception. However, even in this case the comparatively low average stand for this treatment is principally due to poor stands on two of the plots where weed growth was particularly dense and vigorous and the beet seedlings were subjected to very severe weed competition prior to thinning.

The IPPC spray, treatment 9, caused no observable effects on either weeds of any kind or the beet seedlings. Since in reports of the control of quackgrass this chemical was applied to the soil, it is possible that the spray used in this case (an emulsion of a toluene solution of the chemical) would not be expected to affect the plants.

Both the salt and sodium nitrate sprays caused evident injury to susceptible weeds such as redroot (*Amaranthus retroflexus* L.), wild buckwheat (*Polygonum convolvulus* L.) and foxtail grasses (*Setaria* spp.) as well as the beet seedlings. In the case of the weeds, evaluation of the effects of the sprays was difficult for the reason that these same weeds are also susceptible to frost injury and had been damaged by freezing temperatures which followed a late season snow storm May 28. However, few, if any, weeds were killed by either the freeze or the sprays. At most, growth of some weed plants had been only slightly checked by burning of leaf edges and damage to the growing tips of the plants. Since beet seedlings had not been appreciably damaged by the freeze, the effect of the sprays was more evident than in the case of the weeds. Both salt and sodium nitrate caused considerable burning of sugar beet leaves. Most of the beet seedlings made quick recovery from the effects of the salt spray, but some that received the sodium nitrate spray were killed.

The cultural practices, treatments 2 and 3, were effective in the control of weeds in initial stands of sugar beets under the conditions of this test. All the area of the ridge-covered plots was essentially weed-free at all times and the sugar beet seedlings made unusually rapid and vigorous growth. Treatment 3, in which the blade weeder was run ahead of the drill shoe at planting, was effective in the control of weeds immediately in the beet rows. Weed growth between the rows of this treatment was as great as in the check plots, but these weeds were killed by the first cultivation and an essentially weed-free initial stand of sugar beets was attained by this method. Growth of the seedlings was nearly as rapid and vigorous as that of the ridge-covered beets and by mid-June there was little apparent difference in the progress and condition of the sugar beet plants in these two treatments.

The cultivation of June 4 to 5 gave fairly effective control of weeds between the rows of treatments 1, 4 to 8 and 12. However the weeds in the row remained and continued to give the beet seedlings competition until the plots were thinned June 24 to 25. The beet seedlings in these treatments made good progress in spite of the weeds, but were markedly smaller when thinned than the beet plants in treatments 2 and 3. As previously noted, since sprays were to be used for weed control on treatments 9, 10 and 11, the plots of these treatments were not cultivated until June 16 when the tractor cultivator failed to do an effective job and the plots had to be cleaned between the rows by hand hoeing June 23. Since the sprays were ineffective, the beet seedlings in these plots were subjected to competition from weeds, both in and between the rows, until just before

thinning. Growth of the beet seedlings in these plots was markedly poorer than with any of the other treatments and at time of thinning many were small and weak. However, counts of the thinned stands indicated that, except for a few plants killed by the sodium nitrate spray, very few beet plants had actually been lost. Weed competition had weakened, but had not killed these plants by late June.

Thinned stands were counted July 3. At that time the beet plants in plots of treatment 2, ridge cover, were growing vigorously and some were touching in the row. The plants of treatment 3 were not quite so large, but were vigorous and making excellent progress. The plants of treatments 1, 4 to 8 and 12, subjected to weed competition only within the row after cultivation on June 5, averaged markedly smaller, but their general condition was good and they were just beginning to make excellent progress. In the case of the sprayed plots, treatments 9, 10 and 11, condition of the beet plants varied from nearly as good as the check on a few plots that had been subjected to the least weed competition to plants that were very small and weak in the plots where weed competition had been severe. Many of these beet plants had only 3 to 5 living leaves and these were small and pale. Also at that time most of the plots of these three treatments had a slight to moderately heavy infestation of sugar beet webworm. Evidently the webworm moths had selected the weedy plots for egg deposition. The plots having the weakest beet plants, where weed growth had been heaviest, had the greatest populations of webworms and had suffered the most damage to the foliage. Damage by the insect on July 3 varied from slight to nearly complete skeletonization of the beet leaves.

Acre yields and percentage sucrose from this test are summarized in table 2. In general, the differences in yield of roots were much smaller than would have been expected from the condition and progress of the sugar beet plants as observed in early July. Apparently, beet plants in this test made remarkable recoveries from the effects of weed competition and insect injury early in the season. However, the yields from treatments 2 and 3, that suffered little, if any, weed competition at any time were the highest of the test and the yields from treatments 9, 10 and 11, that had been subjected to severe weed competition and some webworm injury, were the lowest. Some differences are slightly above the difference required for statistical significance at the 5-percent point. None of the treatments affected quality of the beets as indicated by percentage sucrose, therefore, the acre yields of gross sugar follow the trends of the root yields.

The results of this test may have some important implications. Ridge cover, as employed in this test consisted of a complete cultivation that stirred all the soil between the rows to a depth of 2 or 3 inches and threw a shallow additional cover of loose dirt on the rows. It gave complete weed control and an essentially weed-free initial stand of sugar beets. However, this cultural practice necessitates two additional cultural operations and involves the risk of having the beet seedlings caught in the ridge should adverse weather prevent the removal of the ridge at the proper time.

**Table 2.**—Emergence and weed-control experiment, Fort Collins, Colorado, 1947. Acre yields of roots and gross sugar and percentage sucrose. (Data given as 8-plot averages.)

| Treatment | Acre yields | | Sucrose |
|---|---|---|---|
| | Roots | Gross sugar | |
| | (tons) | (pounds) | (percentage) |
| 1. Check: no treatment | 14.98 | 4256 | 13.99 |
| 2. Ridge cover | 15.73 | 4419 | 13.96 |
| 3. Blade ahead of drill | 15.61 | 4472 | 14.16 |
| 4. Mulch: powdered alfalfa | 14.26 | 4000 | 13.95 |
| 5. Mulch: chopped alfalfa | 15.15 | 4276 | 13.91 |
| 6. Mulch: rotted manure | 15.25 | 4355 | 14.04 |
| 7. Mulch: fresh manure | 14.86 | 4227 | 14.05 |
| 8. Salt: side dress after thinning | 15.42 | 4371 | 14.03 |
| 9. IPPC: spray before thinning | 14.05 | 3976 | 14.00 |
| 10. Salt: spray before thinning | 13.93 | 3921 | 13.97 |
| 11. $NaNO_3$: spray before thinning | 13.61 | 3824 | 13.85 |
| 12. "Fertidene": at planting | 15.15 | 4263 | 13.93 |
| General mean of experiment | 14.83 | 4197 | 13.99 |
| F value | 2.03* | 1.83 | [1] |
| 2 x the S. E. of a difference | tons | pounds | |
| (Odds of 19 : 1) | 1.39 | 445 | |
| S. E. of mean in percentage of general mean | percentage 3.31 | percentage 3.75 | percentage 1.54 |

[1] $V_e$ exceeds $V_t$.

A blade weeder knife run flat at a depth of about 1 inch immediately ahead of the drill shoe at planting effectively controlled weeds in the beet row itself. Since weeds between the beet rows were killed by the first cultivation this treatment also produced an essentially weed-free initial stand of sugar beets. This treatment has the advantage over ridge cover of requiring no additional cultural operations and involves no risk to normal emergence of the sugar beet seedlings. In this test the yields of roots and sugar per acre were approximately identical from these two treatments and slightly higher than the yields from any other treatment used.

In this experiment spraying with IPPC, salt, or sodium nitrate was ineffective as a weed control. The IPPC spray, as used, had no apparent effect on weeds or sugar beet plants. The salt spray slightly burned the leaves of susceptible weeds and beets, but killed neither. The sodium nitrate spray killed a few beet plants and may have damaged susceptible weeds slightly more than the salt spray, but was also ineffective as a weed control.

### Application of Chemicals to the Soil

Because of lateness of the season and other considerations, the work undertaken on this phase of weed-control investigations in 1947 was much curtailed from the originally proposed cooperative project between the Division of Sugar Plant Investigations and the Division of Fruit and Vegetable Crops and Diseases.[5] The project in its curtailed form consisted of four observation blocks each approximately 60 by 60 feet in size. To three of these, chemicals were applied on the surface of the soil and the fourth was held untreated as a check. These blocks were a part of the 10-acre field used for general sugar beet experiments on the Agronomy Farm of

[5] The writer is indebted to J. W. Mitchell, P. C. Marth and L. W. Kephart for suggestions relative to timing of applications and the amounts of the chemicals to use in these preliminary trials.

the Colorado Agricultural Experiment Station at Fort Collins, Colorado, and on each a series of sugar beet plantings were to be made at approximately weekly intervals.

The land had not been worked from April 21 to May 15, hence a moderately heavy growth of weeds was present when work was started on the latter date. The 2-4-D was mixed with dry sand and broadcast by hand on the appropriate blocks after which the whole area of the test was cultivated with a springtooth cultivator and smoothed with a harrow. Both these tools were run in a direction diagonal to that of the beet rows subsequently planted. The shipment of IPPC was not received until 2 days after this cultivation. It was applied May 18 to its appropriate block in the same way as the 2,4-D but on the cultivated surface and was lightly worked into the surface of the soil with a rotary-type garden cultivator. Thus the 2,4-D was mixed into the surface 3 to 4 inches of soil and the IPPC only into about the surface inch of soil. Showers totalling nearly 1 inch of precipitation had occurred in the period May 9 to 12 and the soil was in excellent condition for working. Practically all weeds were killed by this cultivation. Frequent showers maintained sufficient moisture in the surface soil for germination of the beet seed planted until near the end of June. Germination of the June 20 planting was nearly normal, but that of the June 27 planting was not complete until after irrigation in July.

The treatments consisted of the application of 10 pounds per acre of 2,4-D on block I, 20 pounds per acre of 2,4-D on block II, 40 pounds per acre of IPPC on block III, and the untreated check block IV.

The first planting of sugar beets was made May 16 following the application of 2,4-D and 2 days before the application of IPPC. Subsequent plantings of beets were made on May 24, May 31, June 6, 16, 20 and 27. The June 27 planting was actually only a replanting of the 2,4-D blocks first planted on May 16 and on which practically no beet plants had emerged.

By the middle of June there was a moderately heavy weed growth on the check block and by the end of June weeds appeared to be giving beet seedlings of the June 16 and 20 plantings severe competition on this block. Both the blocks treated with 2,4-D and the block treated with IPPC were essentially weed-free in mid-July and remained nearly weed-free for the balance of the season. Only a few weeds, chiefly purslane, appeared late in the summer on the open areas of the blocks treated with 2,4-D. In the case of the block treated with IPPC the beets had made sufficient growth to have smothered any weeds appearing in late summer.

Notes taken July 5 of the initial stands of sugar beets present at that time on these plots are summarized in table 3. In general the effects from the 20-pound rate of application of 2,4-D had been more lasting than the effects of the lighter rate. Practically no beets were found on either the May 16 or May 24 planting on either of the 2,4-D blocks. Beginning with the third planting of beets on May 31, a little over 2 weeks after the appli-

cation of 2,4-D, there was a gradual increase in the number of sugar beet plants that had emerged and survived from the successive plantings until the June 27 planting. Emergence of this planting was very sparse due to insufficient moisture for germination. However, the more or less uniform partial emergence of beet seedlings indicated that the effects of the 2,4-D on germinating beet seed had ceased on the block to which 10 pounds per acre of the chemical had been applied and had practically ceased on the block receiving the heavier application of the chemical. In this test it required approximately 6 weeks' time to dissipate effects of applications of 10 and 20 pounds per acre of 2,4-D to a sufficient degree to permit nearly normal emergence of sugar beet seedlings.

**Table 3.—Chemical treatment of soil test, Fort Collins, Colorado, 1947. Summary of emergence and survival of sugar beet seedlings from seed plantings at intervals after chemicals were applied. (Notes taken July 5, 1947.) Beet seedlings rated as initial stands.**

| Date beets planted | Block I. 2,4-D. 10 lb. per A. May 15, 1947. | Block II. 2,4-D. 20 lb. per A. May 15, 1947. | Block III. IPPC. 40 lb. per A. May 18, 1947. | Block IV. Check, no treatment. |
|---|---|---|---|---|
| May 16 | None | None | Fair to good | Excellent |
| May 24 | None | None | Fair to good | Excellent |
| May 31 | Very few | 2 plants | Fair to good | Excellent |
| June 6 | Very few | Sparse | Good | Excellent |
| June 16 | Thin | Sparse | Good | Good |
| June 20[1] | Thin | Very few | Thin | Thin |
| June 27[2] | Very thin | Very thin | ---------- | ---------- |

[1]June 20 planting made just as soil moisture barely sufficient for germination of seed. Weeds abundant on check plot.

[2]Soil moisture definitely short for normal germination of seed. This was a replanting of the 2,4-D blocks where the May 16 planting had failed.

On the block treated with 40 pounds per acre of IPPC emergence of sugar beet seedlings from the first three plantings appeared to have been slightly delayed and early growth of these seedlings may have been slightly less vigorous than in the comparable plantings on the check block. Seedlings from the later plantings unquestionably emerged and grew normally.

On June 27 all palntings on the check block were cultivated and the first three plantings thinned. The three plantings having corresponding planting dates on the IPPC block could have been thinned at the same time, but were left for observation during a Field Day planned for the Agronomy Farm for early July. In late July all the blocks of the test were hoed and at that time some beets cut out of the plots not thinned on June 27. In general, this may be regarded as a poor job of long-handled-hoe thinning and was particularly poor on the first three plantings of the IPPC block because of the large size these beets had attained by that time.

None of these plots were harvested for yield. However, approximately 60 feet of row from each planting on each block was dug and the beets counted and weighed in mid-October. Root counts and weights of these beets are summarized in table 4. Since different dates of planting and differences in thinning are involved the root weights probably have no significance. The number of beets harvested is some measure of the effect of the chemicals on emergence and survival of sugar beet plants on the chemically

treated blocks. The number of beets harvested from the successive plantings on the check block may in the same way reflect the effects of weed competition.

When 2,4-D was applied at the rate of 10 pounds per acre emergence of beet seedlings was practically inhibited for at least 2 weeks, the effect of the chemical had been partially dissipated at 3 weeks and practically normal thinned stands were obtained after 4 weeks. When 2,4-D was applied at 20 pounds per acre the effects appear to have persisted for about 2 weeks longer, but were probably entirely dissipated by the end of June or about 6 weeks after application.

**Table 4.—Chemical treatment of soil test, Fort Collins, Colorado, 1947. Number and weight of beet roots harvested from 60 feet of row per plot October 14, 1947. (Data given as single-plot values.)**

| Date beets planted | Block I. 2,4-D. 10 lb. per A. May 15, 1947 | | Block II. 2,4-D. 20 lb. per A. May 15, 1947 | | Block III. IPPC. 40 lb. per A. May 18, 1947 | | Block IV. Check, no treatment | |
|---|---|---|---|---|---|---|---|---|
| | (roots) | (wt.) | (roots) | (wt.) | (roots) | (wt.) | (roots) | (wt.) |
| May 16 | None | --- | 1[1] | 1.7 | 35 | 28.4 | 59 | 60.9 |
| May 24 | 3 | 1.8 | None | --- | 34 | 38.4 | 55 | 48.6 |
| May 31 | 7 | 7.3 | None | --- | 42 | 39.9 | 54 | 42.9 |
| June 6 | 23 | 17.3 | 3 | 4.3 | 52 | 38.8 | 49 | 32.7 |
| June 16 | 32 | 26.4 | 7 | 7.5 | 43 | 26.4 | 33 | 28.4 |
| June 20 | 37 | 30.8 | 18 | 17.7 | 28 | 32.0 | 37 | 28.7 |
| June 27[2] | 28 | 18.5 | 37 | 19.4 | -- | --- | -- | --- |

[1]This beet was possibly from the June 27 planting, but appeared to be an older beet. If from the May 16 planting, it was probably an escape on a spot in the row that received none of the chemical.

[2]June 27 planting was a replanting of the 2,4-D blocks where the May 16 planting had failed.

There is no evidence that IPPC applied at 40 pounds per acre in this test materially reduced the emergence of sugar beet seedlings or prevented their survival. Such differences in stand, as are indicated by the number of roots harvested from these single rows, were most likely, due to normal variability and careless thinning of these plots. The low weight of roots harvested from the first planting on this block may or may not reflect an effect of the chemical. Further tests with better control of all factors will be necessary to decide this point.

It is probable that weed competition contributed to the lower numbers of roots harvested from the June 16 and 20 plantings on the check block. These plantings were very weedy when hoed and thinned in late July and elimination of the weeds was the chief concern of the laborers doing this job. In fact, the greater number of beets harvested from the June 20 planting on the IPPC block, in comparison with the check, may be directly due to the absence of weeds on the IPPC block at that time.

In this test applications of 10 and 20 pounds per acre of 2,4-D and 40 pounds per acre of IPPC practically eliminated weed growth for the balance of the season. Since both monocotyledonous and dicotyledonous weeds emerged in appreciable numbers on the check block during the same time it appears that both chemicals were equally effective in controlling

both types of weeds. It seems unreasonable to believe that IPPC would inhibit growth of dicotyledonous weeds and at the same time permit emergence and normal growth of sugar beet seedlings. In this test the chemical was very lightly worked into the surface soil and it is probable that the beet seed was placed below the zone of soil holding most of the chemical. Additional tests of these chemicals are necessary before conclusions are possible as to their effectiveness as weed controls for the sugar beet crop.

## Summary

In tests conducted at Fort Collins, Colorado, in 1947, neither common salt nor sodium nitrate proved effective in killing weeds in sugar beet rows when the chemicals were applied as sprays to weedy rows of sugar beet seedlings prior to thinning. The spray solutions were made by dissolving 2½ pounds of chemical per gallon, and the application rate was about 90 gallons per acre. A spray of IPPC, approximately 5 pounds per acre, also was ineffective.

Ridge covering directly after planting followed by removal a few days later of the excess soil above the drilled seed was highly effective in preventing initial growth of weeds; a planting-time cultivation of the beet row obtained by placing a weeder blade immediately ahead of the drill shoe of the seeder to run at a depth of about 1 inch effectively prevented weed growth in the drill row itself, but weeds grew abundantly in the middles. These were eliminated by ordinary cultivation. Ridge cover, as used in this test, would have advantages if very heavy emergence of weeds was expected. With moderately heavy emergence of weeds, such as occurred in this test, the use of the blade weeder was as effective as ridge cover so far as weeds in the drill row were concerned and has the advantage that no additional cultural operations are involved and there is no risk to emergence of sugar beet seedlings.

In a preliminary experiment 2,4-D (10- and 20-pound per acre rates) and IPPC (40-pound per acre rate) were applied as surface treatments. Both chemicals almost completely prevented weed growth throughout the balance of the season. Dependent upon application rate, 2,4-D required 3 to 6 weeks for the chemical to dissipate enough from the soil so that sugar beet seedlings could emerge. On the other hand, IPPC had only slight effect even when the sugar beet seeds were planted at about the time of its application to the soil.

# Salt Sprays for the Control of Weeds in Sugar Beets in the Pacific Northwest[1]

RAY A. PENDLETON[2] AND VIRGIL H. FREED[3]

SALTS WITH HIGH SOLUBILITY, such as sodium chloride and several of the common fertilizer materials which apparently kill plants by plasmolysis when sprayed or otherwise deposited on the leaves, have been successfully used to eradicate certain weeds from crop plants. Their effectiveness in killing weeds depends on several factors such as age of the plant, type of leaf surface, climatic conditions and type of growth. Their effectiveness in controlling weeds depends on the relative tolerance of the respective plants under conditions in which a kill can be effected.

Sugar beets and table beets have a relatively high tolerance to salt toxicity and the use of salt sprays may have some application in controlling broadleaf annual weeds in these crops. Sodium chloride has had more popularity than other salts for this purpose in some areas, but in the Pacific Northwest this material is of no value as a soil amendment, whereas the nitrogenous salts are useful as fertilizer materials in addition to whatever herbicidal effect they might have. A few tests have been made with some of these salts for the dual purpose of controlling weeds and obtaining the fertilizing benefits. Several other chemicals were included for comparative purposes.

## Early Spring Trials in the Willamette Valley

The first trials were made in the Willamette Valley in February, 1947. The principal weeds were chickweed (*Stellaria media*), mustard (*Brassica arvensis*), and annual bluegrass (*Poa annua*). At this season humidity averages rather high and rainfall may be frequent. The beets were well advanced and the weeds rather large and tough. Several salts as well as other chemicals were sprayed on the leaves. Among these were: ammonium sulfate 320, 480, and 1,000 pounds[4], ammonium nitrate 320 and 480 pounds, sodium chloride 500 and 1,000 pounds, a mixture of ammonium sulfate 160 and Sinox 1 pound, a mixture of ammonium sulfate 500 and ammonium-ortho-secondary 3.5 dinitro-phenate 1 pound, a mixture of ammonium-ortho-secondary 3.5 dinitro-phenate 1 pound and Iso-propylpenyl carbamate 1 pound, a 1:1 mixture of kerosene and gasoline 60, 80 and 100 gallons, Stoddart solvent 80 gallons, and Avon weed killer 50 gallons. These were applied in rod-square plots in the middle of a field and not replicated. The

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[4]Figures show rates per acre.

adjacent area served as a check for observations. None of the materials were effective in killing weeds under these conditions although a temporary mild burning of leaves was caused by some treatments. Results might be consistently different at another time of year. The heavy rates of nitrogen salts had a marked fertilizing effect on both weeds and beets.

### Trials in Central Oregon in April, 1947

On April 18 a number of materials were tried on beets near Redmond, Oregon. The principal weeds were vetch, (*Vicia* spp.), filaree, (*Erodium circutarium*), and quackgrass, (*Agropyron repens*). The weather was dry and cool at the time of the treatments. The beets had gone through the winter in the field, had started spring growth and were relatively tough. The vetch had made a vigorous growth and had a relatively large amount of leaf surface. Plots were made 1 rod square and not replicated. The treatments and percentage kill on beets and vetch are given in table 1. Beets at this age were tolerant to large amounts of salt and the vetch could be eradicated with moderate success by the heavier treatments. Ammonium sulfate was the least effective and also seemed to be the least selective of the nitrogen salts tried. Ammonium nitrate in the heavier rates "burned" back the beet leaves to some extent but the plants soon recovered. It was the most effective in killing vetch, although sodium nitrate or sodium chloride would effect a kill if used in sufficient amount. None of the other chemicals were sufficiently selective to be of any value. Filaree seemed to be just as tolerant as the beets to any of the materials used. Quackgrass was not materially injured. Figure 1 illustrates the general appearance of the plants after treating.

**Table 1.—Treatments and their effects on beets and vetch in the Central Oregon area.**

| Materials used | Rate per acre pounds | Approximate kill | |
|---|---|---|---|
| | | Vetch percentage | Beets percentage |
| Ammonium sulfate | 500 | 25 | 0 |
| Ammonium nitrate | 500 | 90 | 5 |
| Ammonium nitrate | 1000 | 100 | 10 |
| Sodium chloride | 500 | 60 | 0 |
| Sodium chloride | 1000 | 90 | 5 |
| Sodium nitrate | 1000 | 90 | 5 |
| Sodium chlorate | 4 | 0 | 5 |
| Sodium chlorate | 8 | 10 | 10 |
| Sodium chlorate | 16 | 50 | 25 |
| A.S.B.Dn.P[1] | 1 | 0 | 0 |
| A.S.B.Dn.P[1] | 2 | 10 | 10 |
| A.S.B.Dn.P[1] | 3 | 50 | 25 |
| 2-4,D | ½ | 50 | 50 |
| 2-4,D | 1 | 95 | 95 |

[1]Ammonium-O-secondary butyl 3,5 dinitro-phenate.

Figure 1.—Salt sprays for weed control near Redmond, Oregon. Plot in foreground had ammonium sulphate at 500 pounds per acre. Lighter plot in center had ammonium nitrate at 500 pounds per acre.

## Willamette Valley Trials in September, 1947

Further field trials were made later in the season on fall-planted beets when they were in the 4- to 6-leaf stage. The principal weed at this time was red-root pigweed (*Amaranthus retroflexus*), with some plants of lambsquarter (*Chenopodium album*), mustard (*Brassica arvensis*), vetch (*Vicia* spp.,) nightshade (*Solanum* spp.,) round-leaf mallow (*Malva rotundifolia*), and purslane (*Portulaca oleaceae*). Plots were 1 rod square and not replicated. The treatments used and approximate percentage kill of pigweed and beets are given in table 2. Figure 2 illustrates the general appearance after treating. The beets were at about the 6-leaf stage at the time of treating and the weeds were a little older than appeared desirable for the best kill. However, it was possible to eradicate effectively red-root pigweed with ammonium nitrate, sodium nitrate or sodium chloride. Ammonium sulfate was less effective. Lambsquarter, nightshade and mustard which were in these plots were not killed by the treatments as used. Vetch was killed where it was exposed so as to get good leaf coverage; however, most of the vetch was small and protected from the spray by beet or weed leaves. In another trial, where round-leaf mallow was abundant, it was not killed by salt sprays in similar amounts.

In small plots at the Talent Station in Southern Oregon where pigweed was very abundant, it was effectively eradicated from beets at about

the 4-leaf stage with a good coverage of approximately 40-percent solution of sodium nitrate. A similar concentration of ammonium nitrate killed both weeds and beets.

**Table 2.—Results of Willamette Valley trials in September, 1947.**

| Materials used[1] | Rate per acre pounds | Approximate kill | |
|---|---|---|---|
| | | Pigweed percentage | Beets percentage |
| Ammonium sulfate | 400 | 50 | 5 |
| Ammonium nitrate | 400 | 100 | 10 |
| Sodium chloride | 400 | 90 | 5 |
| Sodium nitrate | 400 | 90 | 5 |

[1]No spreader was used with these materials which were mixed with 1 gallon of water per square-rod plot.

Figure 2.—Salt sprays for weed control near Salem, Oregon. Darker block at left center had ammonium nitrate at 400 pounds per acre. All pigweed was killed.

## Greenhouse Results

In greenhouse trials tops of sugar beets at the 6-leaf stage when dipped in the solution were killed by 40-percent ammonium nitrate and slightly damaged by 40-percent sodium nitrate or 30-percent ammonium nitrate when no spreader was used. Vatsol added to the salt solution at the rate of 3 to 4 drops per 50 cubic centimeters decreased injury to the beets, but increased toxicity to lambsquarter. Thirty-percent sodium nitrate or 20-

percent ammonium nitrate when used with the spreader did not damage the beets.

Lambsquarter at 4 to 6 inches high was killed by 20-percent or stronger solutions of ammonium nitrate and 40-percent sodium nitrate either with or without the spreader. Sodium nitrate at 20-percent solution plus the spreader killed these weeds but when used without the spreader caused only a mild "burn."

Limited greenhouse tests with round-leaf mallow and mustard indicate that burning back the leaves with ammonium nitrate does not destroy them.

## Summary

Salt sprays, even at high rates (1,000 pounds per acre), were relatively ineffective in killing weeds in the Willamette Valley in early spring. Apparently climatic conditions and the age of the plants were unfavorable at this season.

In central Oregon in late spring, vetch was readily eradicated from beets by heavy salt-spray treatments.

Salt sprays effectively eradicated certain annual broadleaf weeds from beets in the Willamette Valley and in the Medford area in early fall. Apparently it is important that the weeds be not too old.

Sodium chloride and sodium nitrate apparently could be used interchangeably with about equal effect. Ammonium nitrate was more toxic to both weeds and beets and should be used at a lighter rate. Ammonium sulfate was less effective than the other salts tried and seemed also less selective in action. Ammonium nitrate at 400 pounds per acre in 160 gallons of water effectively eradicated susceptible weeds and killed only 5 to 10 percent of the beets. Sodium chloride or sodium nitrate at similar rates eradicated the major part of susceptible weeds and were not harmful to the beets.

For Pacific Northwest conditions either of the nitrate salts would be preferable to the sodium chloride due to the residual fertilizer value. Only a few weeds seems to be susceptible to eradication by these salts. Red-root pigweed, if not too large, is readily killed. Vetch can be killed at most any size, provided the leaves are exposed so they can be treated. Lambsquarter, mustard, nightshade and round-leaf mallow are more resistant. Filaree seemed to be fully as salt tolerant as the beets. Grasses and perennial weeds were not appreciably injured by the salts.

Under greenhouse conditions, where the leaves were dipped in the salt solution, lambsquarter at 4 to 6 inches high was readily killed by 20-percent ammonium nitrate or 20-percent sodium nitrate plus a spreader. The spreader did not seem to add much effectiveness to the ammonium nitrate on the lambsquarter but made it less toxic on beets.

Such materials as sodium chlorate, 2-4, D and ammonium O-secondary-butyl-dinitro phenol seemed to be just as toxic on beets as on the weeds.

None of the materials tried were effective in eradicating annual bluegrass or established stands of quackgrass.

# Results of Weed-control Experiments in Sugar Beet Fields in the Eastern Area in 1947–A Progress Report[1]

BY G. E. NICHOL

TWO METHODS of weed control were studied in the Eastern Area in 1947. They were: (a) Pre-emergence spraying, and (b) post emergence or selective spraying.

## Pre-Emergence Spraying

A late planting season combined with excessive rainfall made it necessary to abandon plans for carrying out the Foundation spraying test as it had been outlined. Instead, Diesel oil was used as the opportunity presented itself, in an effort to determine the feasibility of such a procedure.

In all cases Diesel oil was applied at rates approximating 100 gallons per acre to which had been added 8 quarts of Dow Contact Herbicide.

All spraying was done late in the season (after June 20) and with one exception all spraying was done on replanted beets.

Here is a summary of what we learned:

1. That Diesel oil fortified with Dow Contact Herbicide will destroy all plant growth above ground. This includes the top growth of biennial and perennial plants.

2. That the material dissipates within a few days and, therefore, does not injure emerging beet seedlings.

3. That weeds which have been covered slightly with soil during planting operations are protected. Therefore, if this occurs, time should be allowed for them to straighten up before spraying is done.

4. That "fogging" and drifting of the spray material will occur if spray pressure is too high and if the nozzles are too high off the ground.

## Selective Spraying

The practice of using common salt (NaCl) in water as a selective weed killer on beets was begun by Dr. G. F. Warren of the University of Wisconsin. The possibilities offered by this method of weed control have created a great deal of interest in the Eastern beet-growing area.

Preliminary work which we did the summer of 1946 gave very encouraging results. Here a saturated salt solution was applied with a hand sprayer. This gave good control on ragweed, smartweed, wild mustard and rough pigweed. The principal annual weeds not affected were lambs-

[1]G. E. Nichol, Farmers & Manufacturers Beet Sugar Association, Saginaw, Michigan.

quarters and purslane. Weed control was much more effective if spraying could be done when the weeds were small.

It was observed that some beets were killed by the spray. Subsequent investigation showed that this killing was principally limited to those plants which had not yet developed their first pair of true leaves.

A power sprayer was purchased in 1947 to conduct field experiments with salt sprays. This machine was equipped to spray four rows of beets. The spray was applied by four fan-type weed nozzles, one being located directly over each row.

The salt solution was made up as the sprayer tank was being filled with water. Two pounds of finely ground NaCl per gallon of tank capacity were placed in the tank. By the time the tank was filled with water, all the salt had gone into solution. A "spreader" or wetting agent was added to the solution to increase its effectiveness.

The rate of application commonly used was 100 gallons of spray per acre. Approximately 100 acres were sprayed on eight different farms in 1947. Results varied from one location to another depending on the kinds of weeds present and their size. In many cases the weeds which were sprayed were not completely killed. However, their growth was stopped until the field could be cleaned up by hand labor. It should be borne in mind that most of this spraying work was done as a last resort before abandoning the field.

The highest rate of application used was 400 pounds (dry weight) of NaCl per acre. This was applied to a portion of a field which we had reserved for our mechanical thinning test. It gave perfect control on ragweed, but only stunted the yellow foxtail which was present. The beets were severely injured. Many plants were completely killed. The remainder were burned so that the crowns turned black and many of the outer leaves died. After about a week or 10 days, these beets began to recover and made excellent growth. At harvest time paired comparisons indicated higher tonnage, percentage sugar, and purity, than those beets which had not been sprayed. We have no logical explanation for this.

A summary of our work with selective sprays is as follows:

1. Common salt (NaCl) in water will control certain annual weeks.
2. Severe injury to beets will occur if they do not have at least one pair of true leaves.
3. Weeds are best controlled when small.
4. Effect on weeds is variable.

Very susceptible:

Annual smartweed

Ragweed

Medium in susceptibility:

Rough pigweed

Wild mustard

Not susceptible:

Lambsquarters

Purslane

At least one grower with whom we worked in 1947 is convinced that spraying saved his crop. He plans to make spraying for weed control a regular practice in his sugar beet growing operations.

# Weed-control Studies on Sugar Beets Using Pre-emergence Treatments

S. W. McBirney[1]

Weed control in sugar beets, particularly in the beet rows, has become more and more of a problem as single-seed, precision-type, sugar beet planters have been developed together with the use of small-sized whole seed, segmented or other processed seed at lower and lower-seeding rates. The increased uniformity and precision of seed drop of these planters, the higher percentage of single-germ seed, and the low-seeding rates have resulted in seedling stands requiring less and less hoeing in the beet row to thin to a desired field stand. As a result, weeds have become more troublesome and part of the savings in thinning labor have been lost because of the need of more weed hoeing later. This was especially pointed out early by the Utah-Idaho Sugar Company. On some of their new-type plantings, the labor needed for weed control in the rows was as much as would have been required for thinning with old-style plantings. Weed control had become one of our chief concerns in sugar beet mechanization by the spring of 1946 and became one of our chief objectives for 1947.

A report in 1946 by L. W. Kephart, United States Department of Agriculture agronomist, on weed control on other crops than sugar beets by pre-emergence control methods, pointed out a promising solution to our weed problem in sugar beets. In his paper[2] he pointed out that few weed seeds would germinate until brought within 3/8 of an inch of the soil surface and only then when moisture and temperature conditions are right. He described methods of pre-emergence weed control, the most applicable being to fit the seedbed and allow the weed seeds to germinate and start, then destroy the weeds by spraying with a herbicide or burning. Planting of the crop is done either immediately before or after the weeds are killed using a planter which causes a minimum disturbance of the soil. Thus, no more weed seeds are brought up near the soil surface to germinate and grow that season.

The 1947 weed-control study on sugar beet plots of the sugar beet machinery project of the United States Department of Agriculture and the Colorado Agricultural Experiment Station at Fort Collins, Colorado, was based on Mr. Kephart's paper. These plots were put in by the Division of Farm Machinery with the cooperation of G. W. Deming of the Division of Sugar Plant Investigations, both of the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Mechanical Engineering, Weed

[1]Senior Agricultural Engineer, Division of Farm Machinery, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture.

[2]L. W. Kephart, "Weed control with chemicals," a paper prepared for presentation at the annual meeting of the American Society of Agricultural Engineers in June 1946 and published in the November 1946 Agricultural Engineering, Vol. 27, No. 11, pages 506-8.

Control Investigations and Agronomy Sections of the Colorado Experiment Station. The plots included six treatments replicated six times in a Latin square. Each plot was 4 beet rows wide by 130 feet long and contained 1/50 of an acre as the beet rows were on 20-inch centers. The treatments were as follows:

1. Pre-emergence control by burning of the weeds.
2. Pre-emergence control by spraying with a herbicide.
3. Control by shallow cultivation just before planting.
4. Control by shallow cultivation and spike-tooth harrowing just before planting.
5. Covered-row planting in the weedy seedbed.
6. Check (no weed-control work).

The plot ground was disked, irrigated, manured and fall-plowed. It was left in the rough during the winter until it was spike-tooth harrowed in February. Seedbed fitting was begun in late March when field work was being started in this section. The field needed considerable spring-toothing and floating to level, and wet weather and wet soil delayed completion of the seedbed until April 21. It was then allowed to lie so that the weeds could sprout and grow. The weed growth was sufficiently advanced by mid May for our planting and pre-emergence weed control, but wet weather delayed the planting until June 6. Figure 1 shows, under the planter, the stage of weed growth at the time planting was done. This was later than we had wanted to plant. We are carrying on this type of weed-control investigations this next season and we plan to get our seedbed fitted in the late fall or early winter, if possible. Our weed growth around Fort Collins usually starts late in April and we hope to do our planting by late April or early May. One objection to weed control by pre-emergence treatments, in areas where seed growth does not start until spring, is the delay in planting necessitated by waiting until weed growth has started.

Planting for all treatments was done with a No. 55 John Deere planter using the new No. 64 planter seed plates and cut-offs and special false plates with 5/8-inch diameter, smooth, slightly curved seed tubes. Double disk openers were used with depth bands set for 1½-inch planting depth and with bevel-rim press wheels set in normal position about ¾ of an inch apart. Small disks were mounted behind the press wheels for the covered-row planting, but were held up off the ground for all of the other plantings.

Segmented seed, 7/64- to 10/64-inch, was used at a seeding rate of 1.85 pounds per acre in 20-inch rows. The planter drives used gave 2.42 seed cells per foot of forward travel or 4.95 inches per cell. Planting speed was 2.35 miles per hour. As the planting was late, 45 pounds per acre of ammonium phosphate (11-48-0) was put in with the seed to start the growth faster.

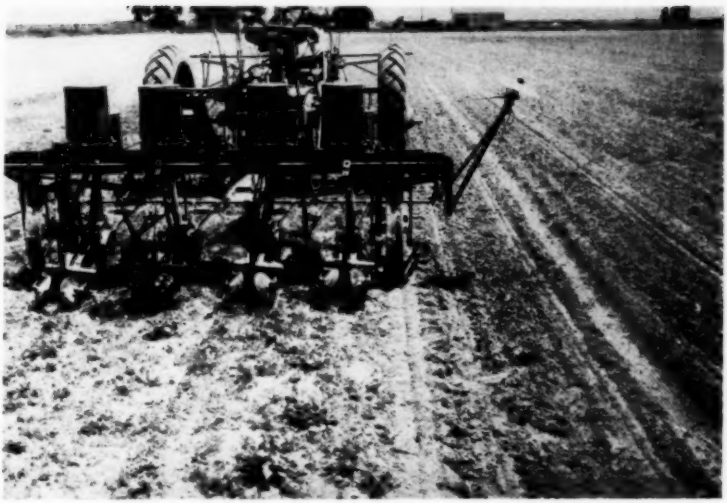

Figure 1.—The sugar beet plots for weed control by pre-emergence burning or spraying were planted right in the weed growth. The four-row plot to the right of the planter was shallow-cultivated just before planting. The small disks at the rear of each opener were used for the covered-row planting, but were lifted as shown for the regular planting.

Planting for treatment No. 1, pre-emergence burning to kill the weed growth was done directly in the weed growth as shown in Figure 1. Burning of the weeds was done with a New Holland, model PNH1-4A, 4-row Sizz-Weeder mounted on a Farmall H tractor as shown in Figure 2. This burner was supplied by the New Holland Machine Company, New Holland, Pennsylvania, for this work and they sent David M. L. Forbes of their company to help us with the adjustment and operation of the machine. The eight burners were set in line in a vertical position on 10-inch centers with their lower ends about 5 inches above the ground so as to cover completely with flame the 4-row beet plot. However, we found later that we got a slightly better weed kill, perhaps, by lifting the burners about 1 foot off of the ground, using the hydraulic lift on the tractor to hold the burners in the desired position. Other positions or burner angles probably might give even more effective weed kill.

The fuel used in the burner was propone and the pressure regulator was set to give 35 pounds per square inch of gas pressure on the burners. The burner is designed for use of either commercial propane or butane. Preliminary tests at tractor speeds ranging from 1.13 to 3.34 miles per hour gave increasing weed kill as the speed decreased though a complete kill was not obtained with one pass even at the slow speed. The weeds were not consumed by the burning, but were wilted immediately and those that did not survive died in a day or two.

The plots in the pre-emergence burning treatment were burned in the afternoon of the day they were planted, using the 1.13 burning speed. The afternoon was mostly sunny with a few short, cloudy periods and the air temperature was 75 degrees. Three days later the plots were burned a second time as some weeds had survived and as complete a kill as possible was desired. This second burning left the plots practically bare as the weeds killed by the first burning were fairly dry and burned up. The burning did not heat up the ground surface to any extent as a hand could be comfortably laid on the ground almost immediately behind the burner.

Figure 2.—A Sizz-Weeder burner was used for the pre-emergence burning immediately after planting. The stage of weed growth at the time of burning can be noted.

Planting of treatment No. 2, pre-emergence spraying with a herbicide, was done the same as for No. 1 directly in the weed growth as shown in Figure 1. The herbicide selected for this treatment was straight diesel fuel oil to be applied at the rate of 50 gallons per acre. This was recommended by W. W. Robbins of the University of California at Davis based on weed spraying done earlier in the spring at Davis. The plots in this treatment were sprayed with the diesel oil on June 7 in the forenoon of the day following the planting. The day was sunny with a very slight breeze and the air temperature was 72 degrees. Our actual rate of application figured out to be 77 gallons per acre. We wanted to put on enough to get a complete weed kill if possible.

The diesel-oil spray was put on with an Essick Model DFWS-3, air-pressure sprayer mounted on a row crop tractor but driven by a small

auxiliary engine. The unit, which was made available by Bruce Thornton in charge of weed-control investigations at the college, is shown in Figure 3 putting on the pre-emergence spray. A short boom with three Binks nozzles with No. 3 orfice disks was used. These nozzles have a rectangular slot opening averaging .086 by .037 inch and give a flat spray. The nozzles were set 15 inches above the ground to spray nearly directly downward on 25-inch centers and gave a good coverage on the 80-inch, 4-row strip of each beet plot. An air pressure of 50 to 55 pounds per square inch was used which gave a discharge of 2.92 gallons per minute for the three nozzles. The outfit was run at 2.8 miles per hour to give the 77 gallons per acre application rate.

The diesel oil used was purchased locally in Fort Collins from the Continental Oil Company. It came from a Wyoming refinery, we were told, and had the following typical specifications which, of course, are for the oil as a fuel and have little value as specifications for a herbicide:

| | |
|---|---|
| Flash | 154 |
| A. P. I. gravity | 40.4 |
| Viscosity at 100 F | |
| Centistokes | 2.53 |
| Saybolt | 34.5 |
| Copper strip corrosion test | O. K. non-corrosive |
| Cetane No. | Corrosive 53-55 |
| Neutralization No. | .025 |
| Sulphur | .05 percent |

By June 10 it became evident that our diesel-oil spray was giving very poor weed kill. A check area kept until June 25, shown in Figure 5, showed that we had not gotten but very little weed kill with the diesel-oil spray. The weeds were largely pigeon grass or yellow foxtail, lambs-quarter and wild buckwheat. Apparently the diesel fuel oil which was used was much less toxic to the weeds than that used in tests carried on by the California Agricultural Experiment Station, the Shell Agricultural Laboratory at Modesto, and others in California.

It was desired to get as nearly as possible a complete weed kill by spraying on a herbicide on this treatment. On Bruce Thornton's recommendation, considering dependability and availability of material, it was decided to respray, using a sodium arsenite solution. This spray was applied on June 11, 5 days after planting, but before the beet seedlings were up. The rate of application desired was the equivalent of 100 gallons of 1-percent solution per acre, but we actually put on somewhat more than this to be sure and get a complete weed kill. There was a gentle breeze which gave a little wind drift of the spray, but the spraying could not be delayed as the seedlings would begin to emerge in a day or two. That evening and night 2.5 inches of rain fell which may have made this spray

treatment somewhat less effective. It did cause a heavy soil crust to be formed which had to be mechanically broken on June 16. This reduced the percentage of seedling emergence somewhat.

This spraying gave a fairly complete weed kill, however, and probably would have been slightly better, particularly at the edges of the plot if it had not been for the wind drift of spray. This sodium arsenite spray reduced the seedling emergence somewhat as the percentage of potential emergence on this treatment was 28.4 percent as compared to 40.5 percent on the burned plots which were planted in the same seedbed.

Figure 3.—The pre-emergence diesel fuel-oil spray was applied immediately after planting, the weed growth being in the stage shown.

For the shallow-cultivation weed control, treatment No. 3, the seedbed was cultivated immediately before planting using nearly flat beet-weeder knives and duck-foot knives working just below the soil surface. The depth of cultivation averaged about 1 inch. The soil was disturbed very little by this cultivation, in fact not enough to kill all the weeds cut off. The ground was moist and some of these weeds continued to grow after the cultivation. The appearance of the seedbed of this treatment after cultivation and planting is shown at the right side of Figure 1.

Treatment No. 4 was planned to be one type of check as it was one method of clean-up of seedbeds which have had to lie or been allowed to lie, after fitting and before planting, and on which the weeds have

sprouted. The seedbed preparation was similar to that of treatment No. 3 except that the shallow-cultivation was followed by spike-tooth harrowing to comb out the weeds cut off and perhaps bring up more weed seed. However, the harrowing was not deep enough apparently to bring up more weed seed or at least unsprouted seed as few new weeds sprouted after this operation. It developed into virtually a more thorough shallow-cultivation than treatment No. 3. The seedling emergence on both treatments Nos. 3 and 4 was poorer than where the seed was planted in the undisturbed seedbed and weed growth on treatments Nos. 1 and 2. The emergence was only 18.6 percent on No. 3, shallow-cultivated, and was 28.2 percent on No. 4 which was both shallow-cultivated and spike-tooth harrowed.

Treatment No. 5 was a covered-row treatment which has been advocated for weed control in the beet row. It consists of throwing a ridge of soil over the planted row at planting time and removing this ridge in about 4 or 5 days just before the beet seedlings develop far enough to emerge from the original level of the seedbed. There are two possible ways in which the covered-row method of planting might aid in weed control. One is that the ridge thrown up covers the small weeds in the row and smothers them before the ridge is removed. The other involves destruction of the weeds by seedbed fitting prior to planting. The ridge over the row prevents the weed seeds in the row from germinating while the beet seed is germinating. When the ridge is removed, just before the beet seedlings are ready to emerge, any weeds which have sprouted on the ridge will be killed. The beet seedlings will then get ahead of the weeds sprouting later in the row.

Our covered-type treatment was planted directly in the undisturbed, weedy seedbed as shown in Figure 4. The small disks had to be weighted to penetrate, but threw up a very satisfactory small ridge about 2 inches high as shown. These ridges quite effectively covered the weeds in the row, but as they had to be removed on June 10, 4 days after planting, to avoid damage to the sprouting beet seedlings when removing the ridges, the weeds were not covered long enough to be killed. The ridges were removed with vertical blades about 12 inches long set at right angles to the rows and mounted on a tractor-mounted beet cultivator by standards and clamps. These blades actually scraped the original surface of the ground when removing the ridges and thereby scraped off and killed some of the weeds in the beet rows. The seedling emergence on this treatment was 32.1 percent as compared with 40.5 percent on the burned plots.

Treatment No. 6 was a check on which the beets were planted in the undisturbed, weedy seedbed the same as for the burning and spraying treatments. No weed control treatment was practiced at planting time.

Figure 4.—A pair of small disks, weighted to improve penetration, was used at the rear of each furrow opener for the covered-row planting.

No thinning was done on these plots. The unthinned beet stands in seedlings per 100 feet on the six treatments were as follows:

| | | |
|---|---|---|
| 1. | Pre-emergence burning | 136 |
| 2. | Pre-emergence spraying | 95 |
| 3. | Shallow-cultivation just before planting | 86 |
| 4. | Shallow-cultivation and spike-tooth harrowing before planting | 95 |
| 5. | Covered-row planting | 107 |
| 6. | Check | .... |

The measure of effectiveness of the weed-control treatments was taken as the time required to clean up the plots by hand hoeing. It was decided that no good beet grower would allow even the cleanest of the plots to go through to harvest without hoeing out the weeds. Therefore, all of the plots were cleaned up free of weeds. The weediest treatments were hoed on June 25 and 26. The No. 6 check treatment shown in Figure 5 was so weedy that it had to be very carefully cleaned up by short handled hoe and hand weed pulling and even then some of the beets were pulled out by mistake.

All of the plots were gone over on July 9, just over a month after planting, with long-handled hoes, to cut out all remaining weeds. This was the first and only hand work done on the burned, No. 1, and cultivated and harrowed, No. 4, treatments and, as can be seen at the right

in Figure 5, little hoeing was necessary. The sprayed plots had been hoed on June 26, chiefly to clean up the edges of the plots where the spray had apparently missed because of wind drift, but comparatively little labor had been required. The clean-up time for the different treatments was obtained by totaling all hand-labor time used on the plots. The time for all the plots is comparatively high as inexperienced high-school boys were used for most of the work and the clean-up was thoroughly done, but the comparative times required for different treatments are indicative of the difference in weediness of the plots.

Figure 5.—The weed growth on the check plot which received no weed-control treatment had progressed to this stage by 19 days after planting. The four-row plot on the right of the check was cultivated and harrowed before planting, the next to the right was a burned plot and the plot at the left was covered-row planting.

The hand labor required to clean up the different treatments free of weeds is shown in table 1. The difference required for significance at the 95-percent level, shown at the bottom of the table, indicates no significant difference between weed control by burning and by weed elimination just before planting by shallow-cultivation and harrowing. This weed control by shallow cultivation just before planting might have been less effective if the planting had gone in a month or more earlier when weed-seed germination conditions before planting would have been less favorable. A shallow working of the soil at the earlier date might have moved unsprouted weed seed to a more favorable location for later germination and growth. This is just one of the unanswered questions in connection with this work.

Table 1.—Hand labor required for weed clean-up.

| No. | Treatment Description | Man hours per acre | Percent of minimum |
|---|---|---|---|
| 1. | Pre-emergence burning | 14.57 | 104 |
| 2. | Pre-emergence spraying | 21.65 | 155 |
| 3. | Shallow-cultivation before planting | 45.21 | 324 |
| 4. | Shallow-cultivation and harrowing | 13.98 | 100 |
| 5. | Covered-row planting | 51.03 | 363 |
| 6. | No weed control | 189.50 | 1355 |
| | Difference for significance | 2.12 | |

If the spraying had given complete weed kill to the edges of the plots, less time undoubtedly would have been required to clean up the sprayed plots and they probably would have required about the same time as the burned and clean-cultivated plots. Weed control by shallow-cultivation where the weeds were not killed or by the type of covered-row planting used was much less effective than the treatments just mentioned as shown by the data. The weediness of the No. 6 treatment, where no weed control was practiced at planting time, is indicated by the extremely large amount of time required to clean it up. However, this is of little practical concern as no beet grower would have planted in the weedy seedbed without cleaning it up at planting time.

The amount of labor required to clean up the weeds in the beet plots, that is about 14 man-hours per acre, might seem to indicate that it would have been almost as well to have used a heavier seeding rate and thin the beets in the usual manner, thereby hoeing the weeds out of the beet rows. However, this was not the case. No cultivating for weed control had been done on these beets, or was done later for that matter, and the time required was for hoeing weeds out of the spaces between the rows as well as in the rows. Then, too, the work was done by low-capacity labor.

The beets in all the plots came along well, probably getting a better start because of the small amount of fertilizer used at planting time. They made a good seasonal growth in spite of the late planting and yielded around 13 tons per acre, about 1 ton per acre less than the factory district average. No separate treatment yields were taken as all plots were practically alike after the weeds were cleaned up.

Not much information could be obtained on the economics of the different treatments as the plots were small. However, some information is available. The Sizz-Weeder used at the rate of approximately 90 pounds or 21.3 gallons of propane per hour with 35 pounds per square inch of gas pressure using all eight burners of the machine. At our fuel cost of 12 cents per gallon in lots over 50 gallons, the cost per hour was $2.56. At a speed of 1.13 miles per hour and a width of coverage of 80 inches, the acreage covered was .91 acre per hour while actually burning, which would take 23.4 gallons per acre would cost $2.81 per acre for one burning. One burning at this rate did not give us a complete weed kill so the plots were burned twice at a fuel cost of $5.62 per acre. However, if two

burnings are necessary, the comparatively small amount of difference between the degrees of kill at 1.13 and 2.5 to 3 miles per hour would indicate that two burnings at higher rates of speed separated by 2 or 3 days might be just as effective as the two at 1.13 miles per hour. During the interval between burnings, much of the weed growth dies and dries so apparently the second burning is more effective than the first. If pre-emergence burning were to be the answer to weed control, considerable more experimentation will be necessary to determine the most effective and economical speeds and burner adjustments.

The spraying treatment of 77 gallons of diesel fuel per acre which was used was not effective in obtaining a satisfactory weed kill. However, others have obtained 97 percent or better weed kill with 50 gallons of diesel fuel per acre, apparently using a more toxic oil than the diesel fuel we used. Assuming that a fuel oil toxic to weeds was available at the same 11 cents per gallon price we paid, the cost of oil for spraying would be $5.50 per acre at the 50-gallon rate. Our rate of application was 2.26 acres per hour, but could be considerably greater by using a longer spray boom with more nozzles covering a wider strip. The sprayer we used probably could have handled 10 to 12 nozzles at the 50 to 55 pounds per square inch pressure used which would have covered around 8 acres per hour at the 2.8 miles per hour speed used when actually spraying. The daily capacity of a spray outfit would of course depend upon the speed and size and the time lost in refilling.

The cost of shallow-cultivation just before planting would depend upon the size of equipment used and speed of travel. It should average somewhat less than the cheapest beet cultivation as the rate of travel could be considerably higher. Covered-row planting would cost little if any more than regular planting after the equipment were purchased. The operation of removing the ridges as we did would cost about the same as beet cultivation. There is a real danger with the covered-row planting which should be mentioned, particularly with early plantings when rains may delay removal of ridges. If we had not removed our ridges on the day we did, the 2.5-inch rain the next day would have kept us out of the field until the ridges could not have been removed without damaging the beet seedlings. The seedlings would have had to come through 2.5 to 3 inches of soil and many would never have lived to emerge.

# Entomology

# Comparative Toxicity of Some New Insecticides to Beet Leafhoppers on Sugar Beets in Idaho, 1947[1]

J. R. Douglass, K. E. Gibson, H. C. Hallock, and W. E. Peay[2]

The development of varieties of sugar beets resistant to curly top has made it profitable to grow beets again in areas of the western part of the United States that are affected by the beet leafhopper, *Circulifer tenellus* (Bak.). These resistant varieties are susceptible to curly top during the early stages of growth. The beet leafhopper is the vector of the virus of this disease. When a large spring movement of beet leafhoppers has coincided with the seedling stage of the plant, serious losses from curly top have occurred in California, Idaho, Montana, Nevada, Utah, Washington, and Wyoming. Although the losses have been local in extent, they have dealt hard blows to growers in affected areas.

In the mechanized program of sugar beet production the development of segmented, or sheared, seed is important in reducing hand labor in thinning. The use of sheared seed has materially reduced the number of plants per acre as compared with the number obtained with the conventional seedball method of planting. Consequently, with fewer plants available, a given number of leafhoppers will infect a larger proportion of plants with curly top.

Giddings (6)[3] showed that resistance of the sugar beet to curly top increases rapidly with the size and age of the plant. Annand *et al.* (*1*) and Douglass *et al.* (4) showed that the magnitude and time of spring movement of the leafhoppers into beet fields are important factors that influence the extent of curly-top epidemics. Hills (8) found that leafhoppers entering the beet fields late in the season are relatively unimportant in causing damage by curly top. Douglass *et al.* (*5*) showed that most of the incoming beet leafhoppers enter the beet fields in continuous movements over a period of several days or during heavy flights of short duration.

In 1947 the initial movement of the spring generation into beet fields on the western edge of the Twin Falls, Idaho, irrigation tract started on May 7. The peak of the movement was reached on May 26, when the average adult population recorded was 1,615 per 100 square-foot samples.

[1]This work was carried out in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering of the United States Department of Agriculture, the State of Idaho Pest Control Commission, and the Idaho Agricultural Experiment Station.

The writers thank T. P. Clugg, F. R. Lawson, F. W. Mogensen, W. N. Oliver, A. J. Stecklein, F. H. Shirck, and L. A. Winkle, Jr., for assisting in this work, and H. C. Manis, University of Idaho, for reviewing the manuscript.

[2]United States Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine.

[3]Numbers in parentheses refer to literature cited.

Seventy-six percent of the leafhoppers entered the fields between May 19 and 26. It is impossible to determine the period between the peak and the end of the spring movement, as there is no practical method of distinguishing incoming leafhoppers from those already there. Apparently, if the young, susceptible plants were kept free from beet leafhoppers for approximately 2 or 3 weeks during the spring movement in outbreak years, curly-top infection would be reduced sufficiently to make control operations profitable. With this thought in mind, we shall confine our discussion to the control of the spring populations.

For years various workers have tried to control curly top by controlling the beet leafhopper. Cook (2), Douglass *et al.* (3), and Romney (9) showed that pyrethrum killed beet leafhoppers but did not have any residual effect. De Coursey[4] found that pyrethrum extract could be used with sulfur without decreasing the effectiveness of either material. Sulfur had a residual effect upon the eggs and young nymphs, but was not effective against the adults and larger nymphs. Experiments with pyrethrum mixed with various sulfurs showed that these materials reduced both adult and nymphal populations present at the time of treatment, but were not effective against adults coming later.

Many materials have been tested at the Twin Falls laboratory of the Bureau of Entomology and Plant Quartine in order to develop an insecticide that would give protection to plants against curly-top infection. The results of field experiments in 1947 are presented herein. These experiments were designed to compare the toxicity of several new insecticides, including their residual effect, when applied in different formulations as dusts, sprays, or mists. Therefore, the work was delayed until high populations of leafhoppers were present in the fields. No curly-top control was planned, as the object was to determine the most effective material in its most efficient formulation.

## Methods

Thirteen experiments were conducted between June 6 and July 18, 1947, in cooperation with Harry A. Elcock, Idaho manager of the Amalgamated Sugar Company, and beet growers of Buhl and Castleford, Idaho. The fields selected for treatment were located on the western edge of the Twin Falls irrigation tract, and were close to the leafhopper spring-breeding grounds that lie to the west of this cultivated area.

The effectiveness of the materials was determined by comparing pre-treatment and post-treatment numbers of adult beet leafhoppers. The counts were made with the Hills (7) square-foot sampler, which traps the insects in a circular cage. The samples, which were taken at random along the beet rows, included more than one plant in unthinned fields but single

[4]De Coursey, J. D. Studies on the effect of certain insecticides on the beet leafhopper with special reference to lime sulfur. Thesis on file at University of Illinois, 1941.

plants in thinned fields. Pre-treatment counts were made either just prior to treatment or the day before, by taking 100 samples in each field, 25 samples in each quarter. Post-treatment counts were made 1, 7, and 15 days after treatment, except in experiment 7, when counts were made after 2, 8, and 14 days. Either 10 or 15 samples per plot were taken, depending on the post-treatment population.

The randomized-block method was used in setting up the experiments. The fields were divided into 16-row parallel plots. The number of plots determined the number of treatments and replications in each field. The number of treatments in each experiment ranged from 3 to 6 and the number of replications from 2 to 9.

Figure 1.—Spraying beets for the control of the beet leafhopper, Castleford, Idaho, June 19, 1947.

All materials were applied with power equipment. The water sprays were applied with a 24-nozzle sprayer mounted on a tractor, as shown in figure 1. This sprayer covered 8 rows at a time. The spray was applied at the rate of approximately 90 gallons per acre except in cases where it was considered advisable to vary the dosage. The pressure was 400 pounds per square inch. The dusts were applied with an 8-nozzle duster mounted on

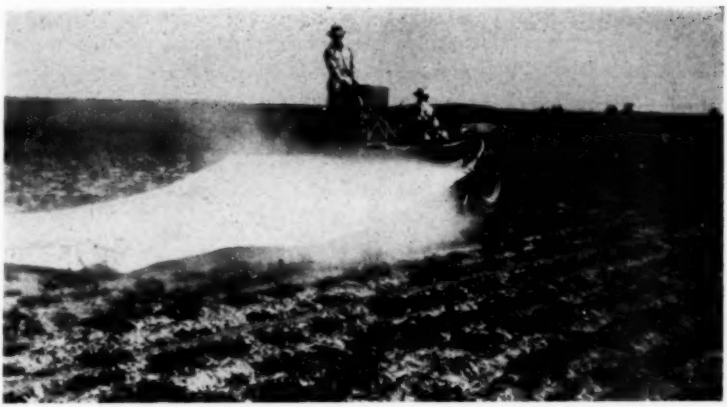

Figure 2.—Dusting beets for the control of the beet leafhopper, Castleford, Idaho, June 15, 1947.

a trailer and attached to a tractor, as shown in figure 2. This duster covered 8 rows at a time and was equipped with a 24-foot trailer-type hood. The mists, or vapor sprays, were applied with a vapor sprayer mounted on a trailer and pulled by a tractor, as shown in figure 3. This sprayer also covered 8 rows with 2 nozzles directed at each row. A pressure of 5 pounds per square inch was used on the liquid side of each nozzle and 12 pounds on the air side. An adjustable wire-glass hood was constructed to reduce the drift of the mist sprays.

Figure 3.—Applying concentrated materials with a vapor sprayer for the control of the beet leafhopper, Castleford, Idaho, June 19, 1947.

Before each treatment, the plots were marked by a white flag placed near the plot stake. As a double check, the numbers of the plots to be treated were given to the spray operator.

The emulsions and vapor sprays were made at the laboratory in steel cans immediately preceding application. The other materials were taken to the fields and either measured or weighed out and added directly to the spray tanks as they were being filled from irrigation ditches. The dusts were used as prepared by the manufacturer.

The weather conditions during the treatments were recorded by instruments located in the fields. Rains fell almost daily from May 27 to June 11 and totaled 2.67 inches. This period of inclement weather delayed the work.

## Insecticides Tested

The following materials were tested, alone or in combination, as dusts, sprays, or mists:

| | |
|---|---|
| Benzene hexachloride | Hexaethyl tetraphosphate |
| Chlordane | Pyrethrum |
| Chlorinated camphene | Sulfur |
| DDT | TDE |

The wettable powders, as well as the oil-soluble and water-miscible chlorinated camphene and pyrethrum extract, were proprietary preparations. The chlordane and DDT were technical grade. The hexaethyl tetraphosphate preparation was stated by the manufacturer to contain 100 percent of hexaethyl tetraphosphate; however, the content of tetraethyl pyrophosphate in this preparation is unknown. The pyrethrum extract contained not less than 2 grams of pyrethrum in each 100 cubic centimeters. The summer oil No. 2, light-medium, contained a minimum of 92 percent of unsulfonated residue and had a viscosity of 60-65 seconds Saybolt. The solvents used were toluene, xylene, and a proprietary nonvolatile solvent, chiefly di- and tri-methylnaphthalenes. The proprietary emulsifiers are hereinafter referred to as emulsifiers A and B. Emulsifier A contained 80 percent of polyakyl aryl polyether alcohol and 20 percent of isopropanol, and emulsifier B consisted chiefly of a phthalic glyceryl alkyd resin. The "depositor" referred to in table 1 was a proprietary "colloidal depositor containing petroleum sulfonates and combined fatty acids." The spreader-sticker listed in the table was a proprietary product, the principal functioning agents being "sodium sulfate of mixed long chains, alcohol—fatty acid esters, and diethylene glycol abietate."

The four emulsions listed in table 1 as A, B, C, and D were as follows (all formulations for 100 gallons of spray): A contained 1.5

pounds of technical DDT, 1,200 milliliters of non-volatile solvent, and 100 milliliters of emulsifier A; B contained 1.5 pounds of technical DDT, 850 milliliters of toluene, and 85 milliliters of emulsifier B; C contained 1 pound of technical chlordane, 450 milliliters of non-volatile solvent, and 126 milliliters of emulsifier A; D contained 1 pound of water-miscible chlorinated camphene, 900 milliliters of non-volatile solvent, and 126 milliliters of emulsifier A.

## Results

Factors influencing control of the beet leafhopper have been discussed (Douglass *et al.* 3). It has also been shown (Douglass *et al.* 5) that cool, cloudy, rainy, and windy weather affect the activity of this leafhopper. In bad weather leafhoppers hide under clods, in cracks, in trash, and between beet-leaf petioles, where they are not hit by the spray. The same factors may also affect the accuracy of the population counts, because the adult beet leafhopper is an extremely active insect.

The results obtained with 41 treatments in 13 experiments on 353 plots totaling 143 acres are given in tables 1, 2, and 3. Although the differences required for significance are given at two levels in the tables, the discussion of the data is based on the 1-percent level.

The data obtained from the sprays and mists are presented in table 1. At the 1-percent level the DDT emulsions gave better reduction in beet-leafhopper populations 1 day after treatment than the DDT suspensions. However, after 7 and 15 days there was no difference between emulsions and suspensions. The addition of pyrethrum, wettable sulfur, or hexaethyl tetraphosphate did not increase the effectiveness of the DDT emulsions. Wettable DDT plus a spreader-sticker or benzene hexachloride was significantly better than wettable DDT plus wettable sulfur after 1 day but not after 7 and 15 days. Generally speaking, all the DDT treatments were significantly better than chlordane, chlorinated camphene, or hexaethyl tetraphosphate.

As mist sprays all the DDT formulations were more effective than the chlordane and chlorinated camphene formulations. There is some indication, however, that chlorinated camphene is more effective than chlordane. In experiment 12, generally speaking, DDT sprays were just as effective when applied at 80 gallons (1.2 pounds DDT) per acre (treatment 33) as when applied at 140 gallons (2.1 pounds) per acre (treatment 30).

Table 2 shows that DDT dust mixtures were significantly better than the chlordane and chlorinated camphene dusts after 1 and 7 days (experiment 5), but that there were no differences after 15 days. Experiment 9 was designed to apply 10-percent TDE dust at 5, 10, 20, and 40 pounds per

acre and to compare the effectiveness of this material with a 10-percent-DDT-sulfur dust applied at 40 pounds per acre. The TDE dust was not very effective after 1 day, but after 7 and 15 days it showed a residual effect which, in most cases, was equal to that of the DDT dust.

In experiment 10 the 38-pound-per-acre application was significantly better than the 10-pound rate after 1 day, but after 7 and 15 days there were no significant differences. All the treatments showed an increase in population over the pre-treatment counts after 15 days.

In experiments 7 and 8 (table 3) the DDT formulations that had previously shown the greatest promise were used. All the formulations were effective against the leafhopper, whether applied as a dust, a mist, or a spray. Since the amount of DDT actually applied per acre was not the same with each type of equipment, a complete evaluation of the three types of applications cannot be made.

The results with outstanding DDT sprays, dusts, and mists applied in two or more fields are compared in table 4. After 1 day, treatment 1 was significantly more effective than treatment 18. After 7 and 15 days there was no significant difference between the two treatments. The addition of pyrethrum extract to the DDT formulations did not increase their effectiveness, as there was no significant difference between treatments 1 and 2 or between 13 and 25 after 7 or 15 days. There was no significant difference between treatments 7 and 8 or between 13 and 14 after 1, 7, and 15 days. The DDT-xylene emulsion was just as effective as the DDT-oil-pyrethrum formulation. Treatment 13, a DDT-oil spray containing pyrethrum extract, was no more effective than treatment 25, a DDT-oil emulsion.

## Summary

In 1947 experiments were conducted in southern Idaho with several new insecticide against the beet leafhopper, *Circulifer tenellus* (Bak.), the vector of curly top on sugar beets. These experiments were designed to compare the toxicity of these materials, including their residual effect, when applied in different formulations as dusts, sprays, or mists. There were 143 acres of beets including 353 parallel plots, 16 rows wide, arranged in randomized blocks.

In general, emulsions of DDT were more toxic than suspensions of this insecticide after 1 day but not after 7 and 15 days. The addition of pyrethrum extract, wettable sulfur, or hexaethyl tetraphosphate did not increase the toxicity of the DDT emulsion.

Chlordane, TDE, hexaethyl tetraphosphate, and chlorinated camphene were relatively ineffective against this leafhopper. DDT was the most effective insecticide tested, whether applied as a water spray, dust, or mist.

**Table 1.**—Change in beet leafhopper population on sugar beet plots after treatment with various insecticides applied as mists and sprays.[1]

| Treatment No. | Materials applied[2] | Plot size (acre) | Rate of application (gallons per acre) | Percent reduction or increase at indicated time after treatment[3] 1 day | 7 days | 15 days |
|---|---|---|---|---|---|---|
| | **Experiment 1, June 6, 6 replicates (Pre-treatment population 803 per 100 square feet)** | | | | | |
| | DDT, 1:5 lb. (emulsion A): | | | | | |
| 1 | Alone | 0.34 | 95 | 98 | 79 | 23 |
| 2 | Plus pyrethrum extract, 1 qt. | .34 | 91 | 98 | 83 | 50 |
| 3 | Plus wettable sulfur, 10 lb. | .34 | 93 | 99 | 80 | 26 |
| 4 | Plus hexaethyl tetraphosphate, 1 qt. | .34 | 91 | 99 | 80 | 45 |
| | Difference required for significance at 5-% level | | | | | |
| | **Experiment 2, June 6, 6 replicates (Pre-treatment population 803 per 100 square feet)** | | | | | |
| | DDT, 50% wettable: | | | | | |
| 5 | 3 lb., plus spreader-sticker, 8 oz. | 0.41 | 87 | 55 | 83 | 47 |
| 6 | 3 lb., plus wettable sulfur, 10 lb. | .43 | 90 | 41 | 86 | 56 |
| 17 | 2 lb., plus wettable benzene hexachloride (6% gamma isomer), 3 lb. | .43 | 92 | 55 | 84 | 49 |
| 18 | DDT, 1.5 lb. (emulsion B) | .42 | 89 | 92 | 85 | 59 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 12 | | |
| | At 1-% level | | | 17 | | |
| | **Experiment 3, June 13, 8 replicates (Pre-treatment population 1,660 per 100 square feet)** | | | | | |
| | DDT, 1.5 lb.: | | | | | |
| 1 | Emulsion A | 0.30 | 97 | 78 | 84 | 55 |
| 18 | Emulsion B | .30 | 95 | 68 | 74 | 62 |
| 19 | DDT, 50% wettable, 3 lb. | .30 | 92 | 33 | 76 | 59 |
| 20 | DDT, 50% wettable, 3 lb. | .30 | 95 | 30 | 80 | 61 |
| | Difference required for significance at 5-% level | | | | | |

**Table 1**—(Cont.).—Change in beet leafhopper population on sugar beet plots after treatment with various insecticides applied as mists and sprays.[1]

| Treatment No. | Materials applied[2] | Plot size (acre) | Rate of application (gallons per acre) | Percent reduction or increase at indicated time after treatment[3] 1 day | 7 days | 15 days |
|---|---|---|---|---|---|---|
| | **Experiment 4, June 13, 5 replicates (Pre-treatment population 963 per 100 square feet)** | | | | | |
| 21 | Chlordane, 1 lb. (emulsion C) | 0.36 | 91 | + 6 | +33 | +47 |
| 22 | Chlorinated camphene, 1 lb. (emulsion D) | .35 | 98 | 11 | +56 | +42 |
| 23 | DDT, 50% wettable, 3 lb. plus summer spray oil, 1 gal., emulsifier B, 8 oz., and "depositor," 1 lb. | .35 | 92 | 73 | 30 | +20 |
| 24 | Hexaethyl tetraphosphate, 1 pt. | .36 | 90 | + 8 | +32 | +62 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 26 | 57 | * |
| | At 1-% level | | | 37 | 81 | |
| | **Experiment 6, June 18, 4 replicates (Pre-treatment population 698 per 100 square feet)** | | | | | |
| | DDT, 4.5 lb. plus: | | | | | |
| 11 | Xylene, 1 gal., and spray oil, 11 gal. | 0.64 | 2.8 | 90 | 23 | 0 |
| 12 | Xylene, 1 gal., emulsifier A, 100 ml., spray oil, 4 gal., and water, 7 gal. | .64 | 3.0 | 97 | 49 | 40 |
| 13 | Pyrethrum extract, 3 qt., xylene, 1 gal., and spray oil, 10.25 gal. | .64 | 2.4 | 99 | 32 | 11 |
| 14 | Xylene, 1 gal., emulsifier A, 100 ml., and water 11 gal. | .64 | 3.0 | 98 | 50 | 32 |
| 15 | Chlorinated camphene, 25% oil-soluble, 18 lb. plus xylene, 1 gal., and spray oil, 11 gal. | .64 | 4.3 | 78 | 36 | 8 |
| 16 | Chlordane, 4.5 lb. plus xylene, 1 gal., and spray oil, 9 gal. | .64 | 2.8 | 47 | 6 | +58 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 14 | 49 | 54 |
| | At 1-% level | | | 19 | 68 | 75 |
| | **Experiment 11, July 3, 8 replicates (Pre-treatment population 1,362 per 100 square feet)** | | | | | |
| | DDT: | | | | | |
| 1 | 1.5 lb. (emulsion A) | 0.42 | 86 | 89 | 63 | 26 |
| 2 | 1.5 lb. (emulsion A), plus pyrethrum extract, 1 qt. | .42 | 86 | 74 | 68 | 40 |
| 13 | 4.5 lb., plus pyrethrum extract, 3 qt., xylene, 1 gal., and spray oil, 10.25 gal. | .42 | 3 | 95 | 57 | 41 |
| 18 | 1.5 lb. (emulsion B) | .42 | 89 | 2 | 65 | 42 |
| 25 | 4.5 lb., plus xylene, 1 gal., emulsifier A, 100 ml., spray oil, 1 gal., and water, 10 gal. | .42 | 4 | 97 | 56 | 46 |
| 26 | 1.5 lb., plus non-volatile solvent, 1,200 ml., emulsifier A, 100 ml., and water, 11.5 gal. | .42 | 3 | 79 | 53 | 43 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 12 | 13 | 18 |
| | At 1-% level | | | 16 | 17 | 23 |

**Table 1**—(Cont.).—Change in beet leafhopper population on sugar beet plots after treatment with various insecticides applied as mists and sprays.[1]

| Treatment No. | Materials applied[2] | Plot size (acre) | Rate of application (gallons per acre) | Percent reduction or increase at indicated time after treatment[3] | | |
|---|---|---|---|---|---|---|
| | | | | 1 day | 7 days | 15 days |
| | **Experiment 12, July 5, 6 replicates (Pre-treatment population 1,050 per 100 square feet)** | | | | | |
| | DDT, 1.5 lb. (emulsion A) plus: | | | | | |
| 30 | Pyrethrum extract, 2 oz. Tractor speed, 2nd gear | 0.45 | 140 | 93 | 75 | 23 |
| 31 | Pyrethrum extract, 2 oz. Tractor speed, 3rd gear | .45 | 121 | 92 | 73 | 20 |
| 32 | Pyrethrum extract, 2 oz. Tractor speed, 4th gear | .45 | 82 | 88 | 70 | 13 |
| 33 | Pyrethrum extract, 2 oz. (Normal amount of stock emulsion doubled per 100 gal.) Tractor speed, 4th gear | .45 | 80 | 86 | 75 | 35 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 7 | 9 | 15 |
| | At 1-% level | | | 9 | 13 | 20 |
| | **Experiment 13, July 18, 5 replicates (Pre-treatment population 1,222 per 100 square feet)** | | | | | |
| | DDT, 50% wettable, 2 lb., plus: | | | | | |
| 39 | Spreader-sticker, 8 oz., and pyrethrum extract, 1 qt. | 0.42 | 114 | -- | 47 | -- |
| 40 | Spreader-sticker, 8 oz., pyrethrum extract, 1 qt., and sulfur wettable, 10 lb. | .42 | 89 | -- | 28 | -- |
| 41 | Sulfur, wettable, 10 lb., plus spreader-sticker, 8 oz., plus pyrethrum extract, 1 qt. | .43 | 88 | -- | 27 | -- |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | | 26 | |
| | At 1-% level | | | | 38 | |

[1]Treatments applied at more than 80 gallons per acre are sprays; those applied at less than 5 gallons are mists.
[2]In 100 gallons of water unless otherwise indicated.
[3]Reduction unless preceded by plus (+) sign.
[4]Not significant according to the F test.

Table 2.—Change in beet leafhopper population on sugar beet plots after treatment with various insecticidal dusts in 1947.

| Treatment No. | Materials applied[1] | Plot size (acre) | Rate of application (pounds per acre) | Percent reduction or increase at indicated time after treatment[2] 1 day | 7 days | 15 days |
|---|---|---|---|---|---|---|
| | **Experiment 5, June 15, 7 replicates (Pre-treatment population 928 per 100 square feet)** | | | | | |
| 7 | DDT-pyrophyllite | 0.28 | 20 | 92 | 53 | 6 |
| 8 | DDT-sulfur | .28 | 19 | 86 | 57 | + 4 |
| 9 | Chlorinated camphene | .28 | 22 | 14 | +24 | +50 |
| 10 | Chlordane | .28 | 18 | 5 | +16 | +55 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 15 | 45 | 49 |
| | At 1-% level | | | 21 | 61 | 67 |
| | **Experiment 9, June 24, 9 replicates[3] (Pre-treatment population 1,291 per 100 square feet)** | | | | | |
| 34 | TDE-sulfur | 0.25 | 3 | +29 | +13 | 45 |
| 35 | TDE-sulfur | .24 | 7 | + 6 | 14 | 34 |
| 36 | TDE-sulfur | .24 | 25 | 35 | 32 | 43 |
| 37 | TDE-sulfur | .23 | 41 | 9 | 55 | 18 |
| 38 | DDT-sulfur | .25 | 41 | 74 | 40 | 44 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 21 | 36 | 17 |
| | At 1-% level | | | 28 | 49 | 24 |
| | **Experiment 10, July 1, 6 replicates (Pre-treatment population 1,112 per 100 square feet)** | | | | | |
| 27 | DDT-talc | 0.42 | 10 | 40 | 44 | + 6 |
| 28 | DDT-talc | .42 | 18 | 65 | 37 | +11 |
| 29 | DDT-talc | .42 | 38 | 72 | 55 | +17 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 18 | 13 | 26 |
| | At 1-% level | | | 26 | 19 | 37 |

[1]Dust mixtures contained 10 percent of active ingredient.
[2]Reduction unless preceded by plus (+) sign.
[3]Treatment 37, 2 replicates; treatment 38, 7 replicates.

**Table 3.**—Change in beet leafhopper populations on sugar beet plots after treatment with various insecticides applied as dusts, mists, and sprays.[1]

| Treatment No. | Materials applied[3] | Plot size (acre) | Rate of application (per acre) | Percent reduction or increase at indicated time after treatment[4] 1 day | 7 days | 15 days |
|---|---|---|---|---|---|---|
| | **Experiment 7, June 19, 6 replicates[2] (Pre-treatment population 1,335 per 100 square feet)** | | | | | |
| | DDT: | | | | | |
| 1 | 1.5 lb. (emulsion A) | 0.61 | 87 gal. | 96 | 95 | 66 |
| 18 | 1.5 lb. (emulsion B) | .61 | 90 gal. | 95 | 89 | 66 |
| 7 | In pyrophyllite | .65 | 15 lb. | 98 | 90 | 62 |
| 8 | In sulfur | .61 | 18 lb. | 96 | 94 | 65 |
| 13 | 4.5 lb., plus pyrethrum extract, 3 qt., xylene, 1 gal., and spray oil, 10.25 gal. | .61 | 3 gal. | 98 | 93 | 54 |
| 14 | 4.5 lb., plus xylene, 1 gal., emulsifier A, 100 ml., and water, 11 gal. | .61 | 4 gal. | 93 | 83 | 67 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 5 | 7 | 13 |
| | At 1-% level | | | 6 | 9 | 18 |
| | **Experiment 8, June 23, 4 replicates (Pre-treatment population 908 per 100 square feet)** | | | | | |
| | DDT: | | | | | |
| 1 | 1.5 lb. (emulsion A) | 0.35 | 90 gal. | 86 | 69 | 15 |
| 18 | 1.5 lb. (emulsion B) | .34 | 91 gal. | 68 | 37 | 9 |
| 7 | In pyrophyllite | .36 | 20 lb. | 86 | 75 | 2 |
| 8 | In sulfur | .36 | 28 lb. | 86 | 75 | + 2 |
| 13 | 4.5 lb., plus pyrethrum extract, 3 qt., xylene, 1 gal., and spray oil, 10.25 gal. | .35 | 2 gal. | 88 | 70 | +13 |
| 25 | 4.5 lb., plus xylene, 1 gal., emulsifier A, 100 ml., spray oil, 1 gal., and water, 10 gal. | .34 | 4 gal. | 87 | 75 | 15 |
| | Difference required for significance: | | | | | |
| | At 5-% level | | | 5 | 26 | 47 |
| | At 1-% level | | | 7 | 36 | 65 |

[1]Treatments applied at more than 80 gallons per acre are sprays; those applied at less than 5 gallons are mists. For dust treatments the rate of application is given in pounds per acre.
[2]Post-treatment population counts were made 2, 8, and 14 days after treatment.
[3]In 100 gallons of water unless otherwise indicated, dust mixtures at 10-percent strength.
[4]Reduction unless preceded by plus (+) sign.

Table 4.—Comparative data on the average results of outstanding treatments applied in two or more experiments.

| Treatment No. | Materials applied[1] | Number of replications | Percentage decrease on indicated days after treatment | | |
|---|---|---|---|---|---|
| | | | 1 day | 7 days | 15 days |
| | DDT, 1.5 lb.: | | | | |
| 1 | Emulsion A (spray) | 24 | 86 | 84 | 45 |
| 18 | Emulsion B (spray) | 24 | 75 | 74 | 52 |
| | Difference required for significance: At 5-% level | | 8 | 8 | 11 |
| | At 1-% level | | 11 | 11 | 15 |
| | DDT, 1.5 lb.: | | | | |
| 1 | Emulsion A (spray) | 14 | 91 | 67 | 22 |
| 2 | Emulsion A plus pyrethrum extract, 1 qt. (spray) | 14 | 81 | 72 | 41 |
| | Difference required for significance: At 5-% level | | 14 | 8 | 23 |
| | At 1-% level | | 20 | 11 | 32 |
| 7 | DDT-pyrophyllite dust | 17 | 93 | 72 | 29 |
| 8 | DDT-sulfur dust | 17 | 90 | 77 | 26 |
| | Difference required for significance: At 5-% level | | 3 | 8 | 18 |
| | At 1-% level | | 5 | 10 | 25 |
| | DDT, 4.5 lb.: | | | | |
| 13 | Plus pyrethrum extract, 3 qt., xylene, 1 gal., and spray oil, 10:25 gal. (mist) | 10 | 98 | 76 | 39 |
| 14 | Plus xylene, 1 gal., emulsifier A, 100 ml., and water, 11 gal. (mist) | 10 | 93 | 72 | 55 |
| | Difference required for significance: At 5-% level | | 7 | 16 | 17 |
| | At 1-% level | | 9 | 24 | 24 |
| | DDT, 4.5 lb.: | | | | |
| 13 | Plus pyrethrum extract, 3 qt., xylene, 1 gal., and spray oil, 10:25 gal. (mist) | 12 | 92 | 57 | 23 |
| 25 | Plus xylene, 1 gal., emulsifier A, 100 ml., spray oil, 1 gal., and water, 10 gal. (mist) | 12 | 94 | 58 | 34 |
| | Difference required for significance: At 5-% level | | 3 | 11 | 17 |
| | At 1-% level | | 4 | 15 | 25 |

[1]In 100 gallons of water unless otherwise indicated; dust mixtures contained 10 percent of active ingredients.

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# Field Insecticide Tests Against the Beet Leafhopper in Sugar Beets Grown for Seed

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CURLY TOP, a virus disease transmitted by the beet leafhopper (*Eutettix tenellus* (Bak.)), has been recognized as a major problem in the production of beet seed in Arizona and New Mexico. Losses are attributable to fall movements of the leafhopper from desert breeding areas to seed-beet fields and are manifested as reductions in seed yield. These movements occur principally in late September and early October, when the beets are small and highly susceptible to curly top. In 1943 Romney (1) described methods of controlling the beet leafhopper. The control was dependent upon the use of insecticides until sufficient foliage covered the ground to create an unfavorable environment for the leafhoppers. At the time this work was published the only satisfactory insecticide known for this insect was an atomized pyrethrum-in-oil spray. This insecticide reduced leafhopper populations at the time of application but had no residual effect; therefore, if additional movements of the leafhoppers occurred after spraying, a second treatment was necessary. The pyrethrum-in-oil also had to be applied with special equipment. For these reasons DDT and other insecticides were tested in the field from 1944 to 1947 with the hope of finding one that would not only give good initial kill but would remain active in the field long enough to avoid the necessity of repeated applications with each leafhopper influx into seed beet fields.

These studies were not conducted as critical experiments but consisted of cooperative field tests in which insecticides were applied with commercial equipment to several acres on different farms. Leafhopper counts were made before and after treatment and, wherever possible, the numbers of leafhoppers remaining in the treated areas were compared with the numbers in adjacent untreated areas. The populations were determined by means of a counting cage (2), that encloses approximately 1 foot of row, the samples being taken at random. The same number of samples per treatment was taken to evaluate comparative treatments on a given date, but the number of samples taken per treatment on different dates or in different fields ranged from 20 to 100, depending upon the magnitude and distribution of the insect population. From 1944 to 1947 the beet-seed-producing district in the vicinity of Safford, Ariz., was subjected to heavier influxes of the beet leafhopper than were the other districts in the Southwest. Therefore, most of the tests were made in this district.

The pyrethrum-in-oil spray contained 0.08 percent of pyrethrins; it was prepared by diluting pyrethrum extract with a mixture of 1 part of

[1]Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, United States Department of Agriculture.
[2]Western Seed Production Corporation

white oil to 2 parts of kerosene. The pyrethrum-sulfur dust contained 0.2 percent of pyrethrins and 50 percent of sulfur. This dust was prepared by diluting a proprietary pyrethrum-extract dust (2.0 percent of pyrethrins) with pyrophyllite and sulfur. All the DDT and chlorinated camphene dusts were diluted with pyrophyllite, except where sulfur was included. The DDT-oil sprays contained a non-burning petroleum oil as the carrier. The DDT water sprays were emulsions or suspensions made from commercial emulsion concentrates or wettable powders, respectively, the contents other than DDT being unknown.

## Tests in 1944

In 1944 tests involving four insecticidal dusts in addition to the recommended pyrethrum-in-oil spray were conducted in two fields in the Safford district. Field 1 consisted of approximately 40 acres, and the tests were made in strip plots of 2 to 5 acres each. All the materials were in dust or powder form, and applications were made by airplane at the rate of approximately 40 pounds of the dust mixture per acre. The materials used and the results are given in table 1. These data indicate that after 1 day no reduction in leafhopper populations could be attributed to the dithiocyanate dust. In the plot treated with sabadilla the decrease in populations was about 37 percent, whereas in the DDT plot it was approximately 87 percent. The 3-day count indicated that there were additional influxes of leafhoppers into the test fields 1 to 3 days after treatment and that only DDT was effective for as long as 3 days. From 8 to 10 days after treatment excessively heavy rains flooded the field, but even under these conditions after 13 days the DDT-treated portion of the field contained only about half as many leafhoppers per foot of row as the untreated check.

Field 2 consisted of approximately 90 acres of seed beets. DDT and sabadilla dusts were tested in different concentrations and the results compared with a pyrethrum-sulfur dust as well as with the recommended pyrethrum-in-oil spray. Except for the pyrethrum-in-oil spray, all the insecticides were applied by airplane to plots approximately 5 acres in size. An attempt was made to apply the treatments at a uniform rate per acre, but differences in the physical qualities of the dusts prevented uniform coverage The results of these tests are given in table 2. The plots sampled 1 day after treatment showed poor results. After the 1-day count the untreated plot was treated commercially and was thus rendered unsuitable for use as a check. Since the counts after 1 and 2 days indicated that the sabadilla and pyrethrum-sulfur dusts had been ineffective, these plots were also treated commercially. Fair results were obtained with the DDT and pyrethrum-in-oil 2 days after treatment, and 1 week after treatment the mean reduction in the leafhopper population for the three DDT plots was 86 percent as compared with 74 percent for the pyrethrum-in-oil plot.

**Table 1.**—Field tests of insecticidal dusts against the beet leafhopper in sugar beets grown for seed. Field 1, Safford, Arizona, 1944.

| Treatment (Figures indicate percent) | Dosage of active ingredients (pounds per acre) | Mean number of beet leafhoppers per foot of row | | | |
|---|---|---|---|---|---|
| | | Before treatment | After treatment | | |
| | | | 1 day | 3 days | 13 days |
| DDT 5 | 2.0 | 0.64 | 0.08 | 0.60 | 0.47 |
| Beta, beta'-dithiocyanodiethyl ether 3[1] | 1.2 | 0.68 | 0.64 | --- | --- |
| Sabadilla 5[1] | 2.0 | 0.60 | 0.38 | 1.32 | --- |
| Untreated check | --- | 0.80 | 0.70 | 1.20 | 0.80 |

[1]Proprietary product.

**Table 2.**—Field insecticide tests against the beet leafhopper in sugar beets grown for seed. Field 2, Safford, Arizona, 1944.

| Treatment (Figures indicate percent) | Dosage of active ingredients (pounds per acre) | Mean number of beet leafhoppers per foot of row | | | |
|---|---|---|---|---|---|
| | | Before treatment | After treatment | | |
| | | | 1 day | 3 days | 13 days |
| Dusts: | | | | | |
| DDT 5 | 1.0 | 0.76 | 0.36 | 0.28 | 0.10 |
| 2.5 | 0.6 | 0.76 | --- | 0.15 | 0.12 |
| 2.5 plus sulfur 75 | 0.9 | 0.76 | --- | 0.15 | 0.10 |
| Sabadilla 20[1] | 5.7 | 0.76 | 0.46 | 0.90 | --- |
| 10 | 2.0 | 0.76 | 0.80 | 0.85 | --- |
| 5 | 1.7 | 0.76 | 0.50 | 1.00 | --- |
| Pyrethrum-sulfur (pyrethins 0.2, sulfur 50) | 0.06 | 0.76 | 0.66 | --- | --- |
| Spray: Pyrethrum-in-oil (pyrethrins 0.08) | 0.03 | 0.76 | --- | 0.16 | 0.20 |
| Untreated check | --- | 0.76 | 0.70 | --- | --- |

[1]Proprietary mixture. For lower concentrations this material was diluted with pyrophyllite.

Since the DDT dusts were effective against the beet leafhopper (tables 1 and 2), a third field of approximately 15 acres was dusted commercially, by airplane, with DDT on October 9. Leafhopper-population studies in other fields in the same locality indicated that additional movements of the insects into the fields under observation had occurred from October 10 to 12. Only a 4-percent DDT dust was available, and 480 pounds were applied to this 15-acre field (1.28 pounds of actual DDT per acre). Beet leafhopper counts showed reductions of 56, 70, 42, and 80 percent of the original populations 1, 2, 3, and 9 days after treatment, respectively, in spite of the additional movements of the leafhopper into the test field.

## Tests in 1945

In the spring of 1945 losses due to curly top in seed beets in the Safford district were heavy as a result of continued leafhopper movements in the fall of 1944. Growers and others interested in the problem observed that the fields treated with DDT in the fall of 1944 contained less curly top than those that had been treated with the recommended pyrethrum-in-oil spray. Therefore, in the fall of 1945 most of the fields in the Safford district were treated with a 5-percent DDT dust applied from an airplane at approximately 30 pounds (1.5 pounds of DDT) per acre. The results in most cases were fairly good, although the reductions were not so great as expected. The beet leafhopper populations in five fields considered to be representative of the Safford district remained at a comparatively low level 10 to 12 days after dusting, the mean number per foot of row ranging from 0.10 to 0.33 as compared with 0.40 to 1.13 before treatment.

In addition to this check on commercial applications of a 5-percent DDT dust, strip plots of approximately 5 acres each were laid out in one 75-acre field of seed beets for the purpose of testing the comparative effectiveness of the recommended pyrethrum-in-oil spray, two DDT-oil sprays, and a 5-percent DDT dust. Both the DDT-oil sprays and the pyrethrum-in-oil spray were applied with a tractor-mounted atomizer sprayer used commercially for leafhopper control; the DDT dust was applied by airplane. The results of these tests, which are given in table 3, show that DDT, either as a dust or as a spray, is at least as good as a pyrethrum-in-oil spray.

**Table 3.**—Field insecticide tests against the beet leafhopper in sugar beets grown for seed. Safford, Arizona, 1945.

| Treatment (Figures indicate percent) | Dosage of active ingredient (pounds per acre) | Mean number of beet leafhopper per foot of row | | |
|---|---|---|---|---|
| | | Before treatment | After treatment | |
| | | | 1 day | 9-12 days |
| Dust: DDT 5 | 1.5 | 0.56 | --- | 0.15 |
| Sprays in oil: | | | | |
| DDT 2.4 | 1.7 | 0.56 | 0.03 | 0.05 |
| | 1.5 | 0.56 | 0.05 | 0.20 |
| Pyrethrum (pyrethrins 0.08) | 0.04 | 0.56 | 0.10 | 0.20 |

In the fall of 1945 beet leafhopper populations became high enough to justify treatment in a few fields in the Salt River Valley, Arizona. Five of these fields were dusted with 5-percent DDT by airplane at the rate of 30 pounds of dust per acre. In these fields the mean number of leafhoppers per foot of row ranged from 0.0 to 0.13 three to ten days after treatment as compared with 0.50 to 0.70 before treatment. Leafhoppers also became fairly numerous in small plots planted primarily for *Lygus* control experiments. Therefore, the same treatment was applied to these plots with hand dusters. Three to 10 days after treatment there was 0.04 leafhopper per foot of row as compared with 0.75 before treatment.

### Tests in 1946

Beet leafhopper populations in the Safford district were again high during the fall of 1946, and considerable dusting was done with 5-percent DDT from airplanes at the rate of 30 pounds (1.5 pounds of DDT) per acre. Population counts were taken in a number of the fields to determine the effectiveness of the control program. In many fields the control was unsatisfactory and tests were made with heavier dosages of DDT. The results of these heavier applications were good and many fields were redusted with either 10-percent DDT at 30 pounds (3 pounds of DDT) per acre or 5-percent DDT at 40 pounds (2 pounds of DDT) per acre. Leafhopper counts were taken in representative fields 2 to 5 days after treatment. Excellent results were obtained with both treatments. The mean numbers of beet leafhoppers per foot of row were as follows:

| Before treatment | After treatment |
|---|---|
| 5-percent DDT | |
| 0.81 | 0.05 |
| 0.60 | 0.20 |
| 0.60 | 0.00 |
| ..... | 0.00 |
| 10-percent DDT | |
| 1.20 | 0.00 |
| ..... | 0.00 |
| ..... | 0.05 |
| 1.26 | 0.00 |

### Tests in 1947

Equipment for applying concentrated liquid insecticides from airplanes had been greatly improved by the fall of 1947, and tests were made against the beet leafhopper to compare the effectiveness of DDT dusts and sprays applied from airplanes and DDT dusts applied with ground equipment. Similar tests were made to compare chlorinated camphene and DDT. Strip plots ranging in size from 3 to 6 acres were marked off in five fields. Table 4 indicates that good results were obtained with all the treatments and that there was little or no difference between sprays and dusts.

Table 4.—Field insecticide tests against the beet leafhopper in sugar beets grown for seed, Safford, Arizona, 1947.

| Field | Insecticide (Figures in percent) | | Type of application: Form | Type of application: Equipment | Dosage of active ingredients (pounds per acre) | Mean number of beet leafhoppers per foot of row: Before treatment | After treatment: 1 day | After treatment: 3-5 days | After treatment: 10-15 days |
|---|---|---|---|---|---|---|---|---|---|
| 1 | DDT | 10 | Dust | Airplane | 3.0 | 0.99 | 0.17 | 0.10 | 0.04 |
| | | | | Ground | 2.0 | 0.99 | --- | 0.12 | 0.08 |
| | | 4.5 | Oil spray | Airplane | 2.0 | 0.99 | 0.04 | 0.47 | 0.02 |
| | Check (untreated) | | ------ | ------ | --- | 0.99 | 0.73 | 1.43 | --- |
| 2 | DDT | 10 | Dust | Ground | 2.0 | 1.18 | 0.07 | 0.24 | 0.05 |
| | | 4.5 | Oil spray | Airplane | 1.7 | 1.18 | 0.13 | 0.97 | 0.26 |
| | Chlorinated camphene | 5 | Dust | Ground | 1.0 | 1.18 | 0.03 | 0.86 | 0.12 |
| | Check (untreated) | | ------ | ------ | -- | --- | 1.03 | --- | --- |
| 3 | DDT | 10 | Dust | Airplane | 3.0 | 0.77 | --- | 0.24 | 0.04 |
| | | 4 | Water spray (emulsion) | Airplane | 2.5 | 0.77 | 0.27 | --- | 0.00 |
| | Chlorinated camphene | 5 | Dust | Airplane | 5.8 | 0.77 | 0.67 | --- | 0.04 |
| 4 | DDT | 10 | Dust | Airplane | 3.0 | --- | --- | 0.22 | 0.02 |
| | Chlorinated camphene | 5 | Dust | Airplane | 1.0 | --- | --- | 0.24 | 0.12 |
| 5 | DDT | 4.5 | Oil spray | Airplane | 3.3 | 0.95 | --- | 0.04 | --- |
| | | | Water spray (suspension) | Airplane | 3.5 | 0.95 | --- | 0.08 | --- |
| | Check (untreated) | | ------ | ------ | -- | 0.95 | --- | 0.62 | --- |
| 6 | Untreated | | ------ | ------ | -- | --- | --- | 0.88 | --- |
| 7 | Untreated | | ------ | ------ | -- | --- | --- | 0.97 | --- |

In fields 1 and 2 additional influxes of leafhoppers are indicated after the 1-day population counts. Later counts, however, indicate that both DDT and chlorinated camphene remained sufficiently active to reduce leafhopper numbers to a low level. The untreated areas in fields 1 and 2 were later treated commercially with DDT dust; therefore, checks on leafhopper numbers in untreated areas in these fields were not possible. Fields 6 and 7 were curly-top-resistant varieties and were, therefore, left untreated. Comparison of leafhopper numbers in these fields with numbers in the treated plots gives further evidence of the value of the various treatments.

## Summary

Field insecticide tests against the beet leafhopper (*Eutettix tenellus* (Bak.) in sugar beets grown for seed have been conducted for 4 consecutive years in Arizona. Materials tested included DDT dusts and sprays, pyrethrum dusts and sprays, chlorinated camphene dusts and sprays, sabadilla dusts, and dithiocyanate dusts. Some tests were also made to compare the efficiency of applications by airplanes with those by ground equipment. These tests indicate that DDT applied at the rate of 2 to 3 pounds per acre will give as good initial kill as the recommended pyrethrum-in-oil spray, and that the residual effect is sufficient to hold leafhopper populations at a low level for at least 1 to 2 weeks after application. The tests also indicate that good results can be obtained with either dusts or sprays containing DDT, and that applications may be made either with power-driven ground equipment or with airplanes. Limited tests in 1947 also indicated that chlorinated camphene may be an effective insecticide against the beet leafhopper.

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# Beet Leafhopper Control With DDT Vapor Sprays

L. G. SMITH[1, 2]

VAPOR SPRAYS have been in use for several years (1)[3]. However, their use until recently, was confined to the control of a relatively few insects and it appears desirable at this time to give a brief description of vapor sprays as referred to in this paper. First of all, they are concentrated sprays, inasmuch as they are applied at only a few gallons per acre. The insecticide or fungicide is dissolved or suspended in a highly refined petroleum oil or in admixture with water. Application is made by means of special vaporizers which break up the material into fine droplets and then project these droplets into a stream of air moving at high velocity. This stream of rapidly moving air, in which the droplets are suspended, swirls about the plants and deposits the toxicant on insects, foliage and stems. As the droplets contact the plants they spread out forming an even film over the surface.

Vapor sprays have received their greatest impetus during the past 2 years from the improvement of airplane application equipment and the development of new chemicals which are effective at low concentrations. A number of advantages may be claimed for vapor sprays: First, because of their concentrated form, considerably less material is handled than when highly diluted liquid sprays are employed. Second, when applied by airplane the droplets settle more rapidly than dusts, thus confining the insecticide application to the field treated. Third, because of their density, applications can be made during periods when moderate winds prevail, a factor which greatly restricts dust application.

Vapor sprays are now used commercially for control of certain insects and plant diseases on practically every crop. They are also used for pre-emergence and selective weedling of a number of crops and in the control of pre-harvest fruit drop on apples and pears. When DDT was made available for field testing in 1945, Shell Oil Company, Incorporated, carried out extensive experiments with DDT vapor sprays for the control of grape leafhopper in the San Joaquin Valley of California. The residual toxicity of DDT vapor sprays was clearly demonstrated by the fact that one application of vapor spray containing 2.4 percent DDT at 5 gallons per acre, applied before blossoming, resulted in outstanding control of grape leafhopper, *Erythroneura elegantula* (Osborn), for an entire season (3).

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[1]Entomologist, Shell Oil Company, Incorporated, San Francisco, California.

[2]The writer acknowledges with thanks the assistance given by G. P. Wright, Spreckels Sugar Company; William Lewis, Agricultural Commissioners Office, Monterey County; E. A. Schwing, Entomologist, California Sugar Beet Processors.

[3]Numbers in parentheses refer to literature cited.

### Tests in 1946

Among the first projects undertaken by the Shell Agricultural Laboratory at Modesto, California, following its opening in 1946, was one on control of insect vectors which transmit virus diseases of plants. Under this project, preliminary field experiments on control of the beet leafhopper, *Eutettix tenellus* (Bak.), were carried out and it was found that an extra light, highly refined petroleum oil containing 2.4 percent DDT by weight (Shell Vapona 1D) applied at the rate of 5 gallons per acre with a Johnston vapor machine gave a high initial kill, but the residual toxicity could not be depended upon for more than 1 week. Approximately 200 acres were also treated commercially by airplane with similar results.

An additional test was made with the same base oil (Vapona 1) containing 4.5 percent DDT by weight[4] on one-half of a 25-acre field of curly-top resistant sugar beets at Five Points, California. Treatments were applied on May 8 with the Shell experimental vaporizer which covers 6 rows with 3 nozzles per row. Beet leafhopper population counts were made with the Hills' sampler cage (3) which covers an area of 1 square foot but because of the size and spacing of the beets each sample consisted of one plant. Pre-treatment counts made on May 7 showed an average population of 20 leafhoppers per plant. Post-treatment counts on May 10 and May 24 showed remaining leafhopper populations of only 0.7 and to 0.9 leafhopper per plant respectively. This test demonstrated residual control for 16 days as the plots were subject to reinfestation from the untreated portion of the field.

### Tests and Commercial Applications in 1947

According to investigators, the potential beet leafhopper population in the Salinas and San Joaquin Valleys of California in 1947, was comparable to that of 1919 when a severe outbreak occurred. Following the initial migration on March 25, many fields were dusted with a dust containing 5 percent DDT, 50 percent sulfur and a diluent at the rate of 30 pounds per acre. On April 14, another general flight took place which necessitated additional treatments. Because of the extended period of migration into the fields and the need for maximum residual toxicity, field trials of DDT vapor sprays by airplane were undertaken. The trials and subsequent commercial applications in the King City and Salinas areas in California were carried out under the direct supervision of William Lewis, Chief Deputy Agricultural Commissioner, Monterey County.

Field trials were made April 28, 1947, with Vapona 1D-045 applied at the rate of 4 gallons per acre by airplane. These trials resulted in an average reduction of beet leafhoppers per foot of row from 3 on April 28 (just prior to treatment) to .003 on May 2 and to .03 on May 17. Because the plots were subjected to continual readjustments in population during the period May 2 to May 17, it was concluded that Vapona 1D-045 applied

[4]Now sold by the Shell Oil Company, Incorporated, under the trademark Vapona 1D-045.

at 4 gallons per acre provided residual toxicity in this area for at least 19 days. Slight injury to beet foliage resulted in some instances where the vapor spray was applied within a few days after a DDT sulfur dust.

Following the 1947 field tests, several thousand acres of beets were treated in various areas of California with Vapona 1D-045 by airplane at 4 gallons per acre during 1947 and results were comparable to those obtained in the trials at King City. In areas where high temperatures occurred following treatment there was some reduction in residual toxicity. To obtain adequate residual toxicity in these areas, a dosage of at least 6 gallons per acre was found advisable, with application directed toward maximum coverage of the undersurfaces of the foliage.

Observations made on the incidence of curly top in treated and untreated fields of resistant varieties in the San Joaquin Valley showed an average of 1 to 3 percent of the plants infected on the treated fields with an estimated yield of 20 tons of beets per acre compared with 60 to 80 percent of plants infected on untreated fields with an estimated yield of 5 tons of beets per acre. In Kern County, California, one field treated with Vapona 1D-045 showed no appreciable damage from curly-top virus and yielded an average of 30 tons of beets per acre. In an untreated field in the same area, 42 acres were abandoned because of damage from the disease and the balance of the field yielded an average of only 8.5 tons of beets per acre. This represented a loss of approximately 50 percent of the potential production of the field. A further comparison of the influence of beet leafhopper outbreaks on the yield of sugar beets during years when commercial control was not available and 1947 is presented in table 1.

**Table 1.—Production of sugar beets during years of severe beet leafhopper outbreaks, Salinas-King City area, California—Spreckels Sugar Co.**

| Year | Acreage harvested | Total yield (tons) | Yield per acre (tons) | Remarks Leafhopper infestation |
|---|---|---|---|---|
| 1919 | 29,300 | 211,895 | 7.23 | Severe outbreak |
| 1922 | 11,715 | 91,000 | 7.43 | Severe outbreak |
| 1925 | 15,793 | 106,267 | 6.73 | Severe outbreak |
| 1947 | 29,880 | 614,000 | 20.6 | Potential same as 1919 |

Improvements in cultural practices since 1925 have resulted in an increase in the average yield per acre from 15 to 20 tons in the Salinas Valley. Development of resistant seed has also been a factor in minimizing crop losses as resistant seed is almost immune to curly-top virus after the plants reach the 10-leaf stage. Even with these developments, leafhopper outbreaks still cause serious losses when uncontrolled in beet fields. The result of the 1947 control program demonstrated that the use of DDT vapor sprays in sugar beet fields, supplemented by foothill control, will give maximum protection to assure normal crop yields in severe leafhopper years.

### Tests on Beets Grown for Seed

Sugar beets grown for seed in the Safford, Arizona, area are subject to beet leafhopper infestations which has necessitated control in order to minimize curly-top virus infection. In recent years, control has been accomplished by use of DDT dust applied both by airplane and ground equipment. This area is also subject to prevailing winds of such velocity as to often cause considerable delay in the dusting operations. Therefore, field tests were conducted during the fall of 1947 to compare the efficacy of vapor sprays applied by airplane with dusts applied by airplane and ground equipment. These tests were carried out in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, Field Station at Phoenix, Arizona, The Western Seed Production Corporation, Phoenix, Arizona, and Marsh Aircraft Company, Inc., Phoenix, Arizona.

Approximately 5 acre plots were used, the total amount of material required for 5 acres being measured and the dosage applied per acre calculated from the area covered. Vapor sprays on fields 1, 2 and 3 were applied by airplane equipped with rotor brushes; on field 4 with an airplane equipped with a spray boom. Dust applications were made by conventional airplane and ground dusters. The beet plants were in the 6- to 8-leaf stage of development at the time of treatment and all population counts were made at random with the Hills' sampler cage covering approximately 1 foot of row. The following materials were applied: 1.—Vapona 1D-045; 2.—DDT emulsion, 1 gallon of 25 percent DDT concentrate[5] diluted with 5 gallons of water; 3.—dust containing 10 percent DDT. The reductions in leafhopper populations by these treatments are shown in table 2.

Following the original migration of leafhoppers, which occurred on or about September 27, an additional flight took place on October 2. Vapor spray applications on fields 1, 2 and 3 were applied under adverse weather conditions with prevailing winds of an estimated 5- to 10-mile per hour velocity. Because of the windy conditions and field obstructions, field 2 received an unsatisfactory spray application. Windy weather delayed the applications of dusts on fields 1 and 3 and a portion of field 2 until after the second leafhopper migration had taken place.

These field tests demonstrated that Vapona 1D-045 gave control of beet leafhoppers for at least 15 days even when applied during periods of moderate prevailing winds. DDT emulsion applied as a vapor spray gave control of leafhoppers for at least 14 days but caused moderate injury to the foliage in the form of necrotic spotting of the leaves. Dusts containing 10 percent DDT gave control of beet leafhoppers from 10 to 15 days when applied during calm weather.

[5]Marketed by the Shell Oil Company, Incorporated, under the trademark Resitox D-25.

**Table 2.**—Field tests of DDT vapor sprays and dusts for beet leafhopper control, Safford, Arizona, 1947.

| Field | Treatment | Treatment date | September 29 | | September 30 | | October 3 | | October 7 | | October 14 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D.A.T. | N.L. | D.A.T. | N.L. | D.A.T. | N.L. | D.A.T. | N.L. | D.A.T. | N.L. |
| 1 | Vapona 1D-045 6 gal/A-airplane | 9/29 | | | 1 | .00 | 4 | .47 | 8 | .24 | 15 | .02 |
| | DDT 10-% dust @ 30 lb/A-airplane | 10/2 | | | | | 1 | .17 | 5 | .10 | 12 | .04 |
| | DDT 10-% dust @ 20 lb/A-ground | 10/3 | | | | | | | 4 | .12 | 11 | .08 |
| | Untreated check | | 0 | .99 | 1 | .73 | 4 | 1.43 | | | | |
| 2 | Vapona 1D-045 @ 5 gal/A-airplane | 9/29 | | | 1 | .13 | 4 | .97 | 8 | .32 | 15 | .26 |
| | DDT 10-% dust @ 18 lb/A-ground | 9/29 | | | 1 | .07 | 4 | .47 | 8 | .42 | 15 | .10 |
| | DDT 10-% dust @ 20 lb/A-ground | 10/2 | | | | | | | 5 | .10 | 12 | .00 |
| | Untreated check | | 0 | 1.18 | 1 | 1.03 | | | | | | |
| 3 | DDT emulsion @ 7½ gal/A-airplane | 9/30 | | | 1/3 | .47 | | | 7 | .20 | 14 | .00 |
| | DDT 10% dust @ 30 lb/A-airplane | 10/4 | — | | | | | | 3 | .24 | 10 | .04 |
| | Untreated check | | — | .77 | | | | | | | | |
| 4 | Vapona 1D-045 @ 6 gal/A-airplane | 10/10 | | | | | | | | | 4 | .04 |
| | Untreated check | | | | | | Samples taken Oct. 8 | | | .95 | 4 | .62 |

D.A.T.—Number days after treatment.
N.L.—Mean number of leafhoppers per foot of row.

**Summary**

Vapor sprays are concentrated sprays in which a toxicant is dissolved or suspended in a refined petroleum oil or in water. Application is made by especially equipped airplane or ground vaporizers which deposit the material on the plants in form of fine droplets. Experiments on the control of the beet leafhopper were conducted by the Shell Agricultural Laboratory at Modesto, California, in 1946 with an extra light, highly refined petroleum oil containing 2.4 percent DDT (Shell Vapona, 1D). Application, made by a ground vaporizer at the rate of 5 gallons per acre, and supplemented by limited commercial airplane applications showed that a high initial kill was obtained with a residual toxicity of 7 days. Additional tests using the same base oil containing 4.5 percent DDT (Shell Vapona 1D-045) applied at a higher dosage resulted in control of beet leafhoppers for at least 16 days. Field tests conducted in 1947 near King City, California, using Vapona 1D-045 at 4 gallons per acre applied by airplane showed an average reduction of beet leafhoppers per foot of row from 3 to .003 at 4 days and .03 at 19 days after treatment. Commercial application on several thousand acres in this area gave comparable results in leafhopper control and resulted in an average yield of 20.6 tons of beets per acre. In areas subject to high temperatures, a dosage of 6 gallons per acre is required. Field tests of various insecticides on sugar beets grown for seed in Safford, Arizona, showed that Vapona 1D-045 applied at 6 gallons per acre by airplane gave control of beet leafhoppers for 15 days. Control was comparable to 10 percent DDT dust applied at 20 pounds per acre by ground duster and at 30 pounds per acre by airplane.

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# Progress Report on the Commercial Control of Lygus on the Sugar Beet Seed Crop in Arizona and New Mexico

by

**Western Seed Production Corporation**

## DEVELOPMENT OF THE LYGUS CONTROL PROGRAM

W. B. Morrow

THE FIRST COMMERCIAL crop of sugar beet seed by the overwintering method was produced on a very small scale in New Mexico in 1927. Several areas are now producing the entire domestic demand of sugar beet seed and also the partial demands of some foreign countries. The production of uniformly high-quality seed has been a major problem because there has been widespread fluctuation in seed viability from year to year. During the early history of the crop, low germination was attributed either to improper irrigation or to unfavorable weather, such as extremely high temperatures accompanied by hot dry winds, during the seed-setting period. The presence of sucking insects such as Lygus and stink bugs was largely discounted and was not considered as being detrimental.

In 1938 the Bureau of Entomology and Plant Quarantine, recognizing the possible importance of insects, established a station at Phoenix, Arizona. Their objectives were (a) the identification of potentially economic insects found to occur in seed fields, (b) the determination of the effect on seed viability and seed yield of the feeding of these insects on sugar beets grown for seed, and (c) the development of control measures which could be utilized against insects found to be of economic importance. Beginning in 1938 cage studies were made and it was discovered that certain sucking insects such as various species of Lygus and stink bugs were capable of causing a great deal of injury to the crop. (1, 2, 3)[1] Germination was greatly reduced, due to the puncture of the seedballs by the insect. The result was low viability seed and its accompanying problems of reduced yields and further complications in the process of cleaning sugar beet seed.

Surveys were made in all areas producing sugar beet seed and every year Lygus were found to varying extent. Because of their widespread distribution and the knowledge that Lygus were capable of causing serious damage to the crop, a major problem was recognized and comprehensive tests were made, both in cages and under field conditions, to determine a satisfactory control that could be universally recommended. A great many materials were tested and certain insecticides such as sulphur, pyrethrum and Sabadilla showed some promise. However, it was not until DDT

[1]Numbers in parentheses refer to literature cited.

was made available that an entirely satisfactory control could be assured. (4) One application of 5-percent DDT at the rate of 30 pounds per acre applied at the early bloom stage gives a most effective control as the kill is complete and the residual effect carries through to harvest.

## EFFECT OF COMMERCIAL LYGUS CONTROL ON SEED VIABILITY IN ARIZONA AND NEW MEXICO

W. B. MORROW

First attempts to control Lygus commercially in the Southwest were made in 1943, in fields having high Lygus counts. One treatment consisted of three to five applications of dusting sulphur applied by airplane at the rate of 40 to 50 pounds per acre. Another treatment consisted of two applications of pyrethrum sulphur. The pyrethrum sulphur showed superiority over the straight sulphur treatment and some increases in germination were obtained.

In 1944 Lygus populations in the Salt River Valley were low and the viability of the seed produced was correspondingly high. No large-scale control was undertaken during that year. However, limited quantities of DDT were available for testing in Arizona and New Mexico. In both areas outstanding results were obtained as Lygus populations were practically eliminated and the residual effect of the DDT held populations to a low level for the remainder of the season.

For the 1945 season Lygus populations were very high in the Phoenix, Arizona, area. Limited quantities of DDT were available for early bloom applications and 300 acres were treated at that time. This acreage remained free of Lygus for the balance of the season and germination averaged 82 percent. Untreated checks of these same fields averaged 54 percent. A difference of 28 percent could be attributed to treatment. During this same period in the Phoenix area a total of 956 acres were dusted with 10 percent sabadilla at the rate of 30 pounds per acre. Preliminary counts showed up to 75 percent mortality but due to the lack of residual effect of the sabadilla, the fields were soon reinfested with Lygus. Seed samples taken from these fields showed only a light increase in germination resulting from treatment.

In 1946 practically the entire sugar beet seed acreage in Arizona and New Mexico was treated with 5-percent DDT applied at the rate of 30 pounds per acre by airplane, or 20 pounds per acre by ground equipment. Lygus populations prior to dusting were not alarmingly high. However, there were sufficient Lygus to cause some reduction in seed viability. As in previous years, one application was sufficient as the residual effect carried through until harvest. The results of Lygus control for this year were outstanding since the average germination for the Arizona crop was 92 percent and for New Mexico 90 percent. The amount of seed produced during this year in the aforementioned areas was 12,397,386 pounds.

From observations made in April of 1947 it was indicated that unless controlled, Lygus populations would be the highest in the history of sugar beet seed production in Arizona and New Mexico. The entire acreage was treated with 30 pounds of 5-percent DDT per acre applied by airplane. Excellent control was obtained and the germination for seed produced in Arizona was 86 percent and in New Mexico 90 percent.

The average germination for Arizona and New Mexico sugar beet seed crops during the years that no effective Lygus control was obtained is compared to years of 1946 and 1947 in figure 1.

These outstanding increases in germination clearly indicate that effective Lygus control plays a major role in the production of uniformly high quality seed. From our experience we feel that even though Lygus populations are low, it is profitable in Arizona and New Mexico to carry on large-scale control programs, treating the entire acreage.

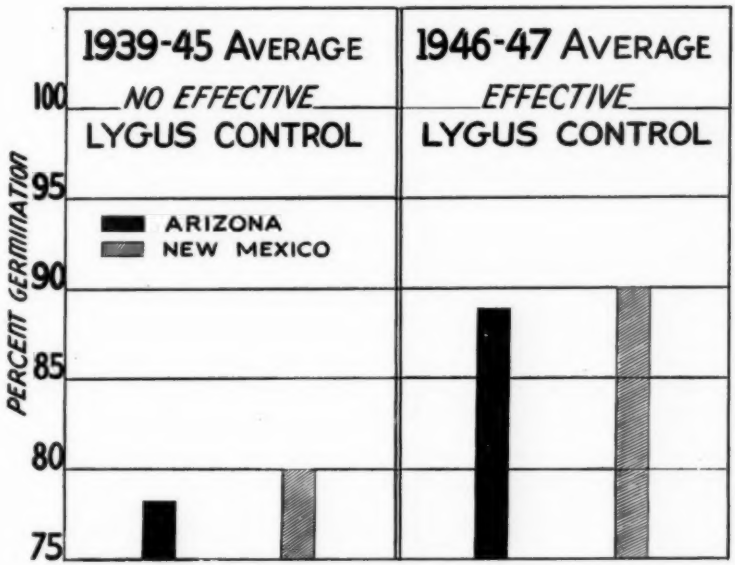


Figure 1.—Effect of lygus control on seed germination.

## EFFECT OF LYGUS CONTROL ON SEED YIELDS IN ARIZONA AND NEW MEXICO

R. C. WOOD

Yield, like germination, has fluctuated widely throughout the history of sugar beet seed production in Arizona and New Mexico, and like germination, the fluctuations in yield were attributed to unfavorable weather

conditions until a relationship between Lygus and germination was known, and effective control was obtained.

Commercial methods of harvesting, threshing and cleaning make it very difficult to obtain yield data from small treated and untreated areas within the same field, therefore, no yield data from small replicated plots has been obtained. Consequently data presented to show a relationship between Lygus population and yield are based on an average for those years in which there was no effective control as compared to the years 1946-1947, in which effective control was obtained.

A comparison of Lygus populations and yields by years for the period 1939-1945 shows that the years of high Lygus populations were the years of lowest yield. The average number of Lygus per one hundred sweeps entering the fields in the Salt River Valley during April for the period 1939 through 1945 are shown in figure 2. The average yield per acre for that period and the same data for the years of effective Lygus control, 1946 1947 are also shown in figure 2. The average number of Lygus entering fields in April was 20 per one hundred sweeps for the years in which Lygus were not controlled and 32 per one hundred sweeps for the years of effective Lygus control. Average yield per acre for 1939-1945 was 1,625 pounds and for the Lygus control years, 1946-1947, 3,246 pounds per acre.

Although many factors other than Lygus effect beet seed production, the outstanding yields obtained under Lygus-free conditions indicate that Lygus control is an important factor affecting seed yields.

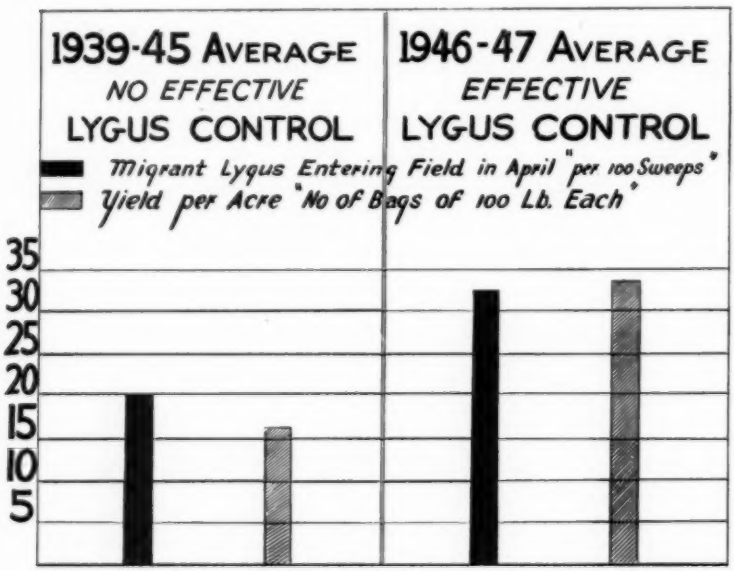


Figure 2.—Effect of lygus control on seed yield.

## THE EFFECT OF LYGUS CONTROL ON SEED CLEANING

A. A. MAST

Since the beginning of the sugar beet seed industry in Arizona and New Mexico, it has been recognized that a direct correlation exists between the viability of field-run seed and the percentage of tare it contains. Figure 3 shows the average Lygus populations entering the beet seed fields in the Salt River Valley in April for the years 1939-45 during which there was no effective Lygus control and for the years of effective Lygus control (1946-47). The percentage tare for these two periods is also shown. From this chart it is apparent that had Lygus not been controlled the past two seasons, the average tare would have exceeded that of the 1939-45 period, whereas it was actually one-third less than for that period.

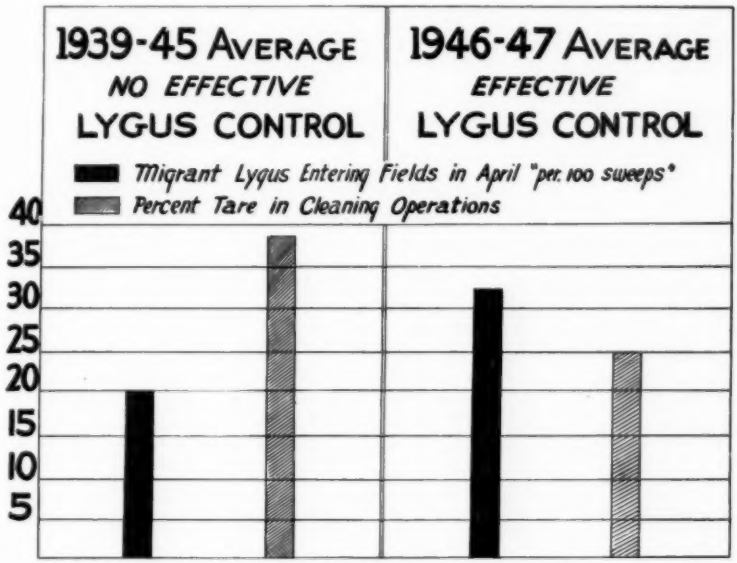


Figure 3.—Effect of lygus control on tare in field run seed.

In those years of low germination and accompanying high tare it has been necessary to reclean or blend large amounts of seed in order to bring the germination of the final product up to the acceptable point. For example, in 1945, a year of high Lygus populations, high tare and low germinations, over 1½ million pounds of seed were blended. Some blending was required every season prior to 1946, but during the past 2 years, owing to the improvement in germination resulting largely from the Lygus-control program, no blending has been necessary.

The improvement in germinations has been accompanied by an increase in weight per cubic foot of seed. In those years of high Lygus populations and no control, seed averaged 12 to 14 pounds per cubic foot. With Lygus control this has been increased to 15 to 18 pounds per cubic foot.

The control of Lygus has reduced the tare of field-run seed by one-third. It has also been responsible for the elimination of blending and an increase in weight of the seed, which has increased cleaning capacity by approximately 50 percent.

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# The Effect of Lygus Control on the Production of Elite Seed

C. W. Doxtator[1]

Beet seed production in the Arkansas Valley of Colorado is confined to the increase of Breeders Stocks, and Elite seed—these being the first increases of improved varieties developed in the Breeding Program of the American Crystal Sugar Company. In order that such improved varieties be made commercially available in good quantity at an early date, it is extremely important that the first productions be obtained in maximum quantity, and of high germination percentage.

Difficulty in obtaining seed lots of high germination percentage has been generally experienced in this area, particularly with breeders stocks, where mother roots, in groups ranging from 15 to 750 beets, are planted in space isolation. Prior to 1940, a germination test of 70 percent on such seed lots was much higher than average, and occasionally seed lots would be obtained having germination tests below 25 percent. Such seed was not usable, and was recleaned to improve germination. Usually little improvement was possible, and so the small quantities of seed had to be planted at unusually high-seeding rates in order to insure the obtaining of a good stand. Further, seedlings from these low-quality productions were found to be very susceptible to damping-off organisms, and seed treatment was always necessary. Failure to obtain satisfactory seed production in the early years was attributed to many factors, such as storage rots in the replanted beets, low soil fertility, lack of irrigation, and unusual climatic conditions.

In 1940 and 1941, entomologists in the commercial beet seed production areas of Arizona and New Mexico (1)[2] were finding large numbers of *Lygus* species in beet seed fields, and had shown that a reduction in the viability of beet seed accompanied Lygus feeding.

## Observations and Control Measures

A check was made for Lygus species on root group isolations in factory districts of the American Crystal Sugar Company in 1942. Lygus was found to be present in relatively small numbers at Oxnard and Clarksburg, California; Missoula, Montana; East Grand Forks and Chaska, Minnesota; and Mason City, Iowa, and in much greater numbers at Rocky Ford, Colorado.

Accordingly, in 1942, No. 10 Pyrocide[3] dust was applied to Elite seed acreages at Rocky Ford in late May, at the rate of 30 pounds per acre, but a

[1]Plant Breeder, American Crystal Sugar Company, Rocky Ford, Colorado.

[2]Numbers in parentheses refer to literature cited.

[3]A proprietary dust mixture containing 0.20 percent pyrethum as a petroleum oil extract impregnated into an inert dust base.

later application was impossible due to the height of the plants. However, all small root group isolations were dusted by hand, and two applications of No. 10 Pyrocide were made.

In 1943, No. 10 Pyrocide was again used, and in larger amounts, to all seed plots. DDT in small quantities was available in 1944 and was used, along with Pyrethrum dusts, to the extent of the supply.

## Results of Lygus Control by DDT

Some DDT was available in 1945, but in 1946 and 1947 adequate amounts were obtainable. Applications of this insecticide in 1946 and 1947 have been made on all plantings of beets grown for seed production, in accordance with the recommendations of Hills, et al (2). On small isolated groups of mother beets, using hand dusters, 10 percent DDT at 50 pounds per acre, applied three times during the late bolting, and early flowering season, has given adequate control. On the larger and overwinter seed increases, one ground dusting of 10 percent DDT at 25 pounds per acre in the mid-season of bolting, and one airplane dusting in the early flowering stage at 40 pounds per acre, has given adequate control of most insects found in seed fields.

Table 1 gives the seed yield per beet and the germination percentage of seed from selected mother beets producing seed in space isolated groups. In table 2 is given the production record of an overwinter planting of Elite seed in 1943 without DDT insecticide control, compared to one in 1947, with one ground and one airplane dusting of DDT for insect control.

**Table 1.**—Average weight of seed produced per beet, and average percentage germination of space isoalted root groups (breeders stock), Rocky Ford, Colorado, 1939-47 inclusive.

| Seed production year | Pounds seed per beet | Average germination percentage |
|---|---|---|
| 1939 | --- | 41.0 |
| 1940 | 0.14 | --- |
| 1941 | 0.23 | --- |
| 1942 | 0.15 | 53.9 |
| 1943 | 0.17 | 64.5 |
| 1944 | 0.14 | 76.4 |
| 1945 | 0.20 | 76.2 |
| 1946 | 0.21 | 87.8 |
| 1947 | 0.28 | 86.5 |

**Table 2.**—Comparison of elite seed production in 1943 without lygus control, and in 1947 with lygus control.

| Description | 1943 | 1947 |
|---|---|---|
| Acreage planted | 20 | 18 |
| Winter season | Very mild | Very severe |
| Percentage winter kill of plants | 25 | 85 |
| Dust treatments | Pyrocide-Sulphur, once | 10 percent DDT, twice |
| Yield per acre | 1077.5 pounds | 874.1 pounds |
| Percentage germination | 39.5 percent | 79.5 percent |
| Final yield of acceptible seed per acre | 225.0 pounds[1] | 874.1 pounds |
| Final germination | 71.0 percent | 79.5 percent |
| Weight per bushel, acceptible seed | 17.5 | 21.0 |

[1]Recleaned five times on standard cleaners; once over gravity table.

## Conclusions

Production of Elite beet seed has shown marked improvement in quality since control of Lygus has been obtained.

DDT in 5- or 10-percent strength and at rates per acre of 25 to 45 pounds, applied one to three times during the bolting and flowering season, has given effective control of this insect in the past 3 years at Rocky Ford, Colorado. As a result, the quantity and quality of seed of new improved varieties was almost double that obtained 10 years ago. The greatest hazard of recent times in this area for the rapid increase of seed from new varieties of sugar beets, appears to have been eliminated.

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# Lygus Damage to Beet Seed in Varying Stages of Development[1]

ORIN A. HILLS AND EDGAR A. TAYLOR

(Abstract)

EARLIER FIELD-CAGE WORK (1, 2)[3] by the senior author showed that various species of *Lygus* (*L. oblineatus* Say, *L. hesperus* Knight, and *L. elisus* Van Duzee) were responsible for the production of nonviable sugar beet seed. In that work *Lygus* bugs were encaged on sugar beets in the early reproductive stages (flower bud or early bloom) and allowed to remain on the plants until the seed matured. There was, therefore, no evidence of the stage of development of beet seed between flower bud and maturity, during which *Lygus* damage occurred. Further studies are in progress to determine more accurately the stage of development of beet seed most susceptible to injury from *Lygus*. These studies to date (1947) have been conducted in field cages of sufficient size to enclose the entire inflorescence of one beet-seed plant. *Lygus* bugs were introduced onto the encaged plants in varying stages of plant development, allowed to remain 1 or 2 weeks, and then killed with insecticides.

Beet seeds develop progressively on the plants; blooming begins at the bases of the spikelets and proceeds towards the tips, so that at no time are all seeds on a plant in the same stage of development. For this reason it was impossible to confine the *Lygus* exposure to a single phase of plant development, but introductions were made when most of the seeds on the test plants were in the desired stage of development. Results from experiments in 1945, 1946, and 1947 indicate that the greatest *Lygus* damage is reduction in seed viability, and that this damage comes during the early seed stage. There is also some indication that reductions in yield may result where plants in the early bloom stage are exposed to *Lygus*. Therefore, until further evidence is available to show more conclusively the effect of *Lygus* upon beet seed on plants in the early bloom stage, particularly as regards yield, the only safe practice is to prevent the accumulation of high *Lygus* populations during the period from early bloom to seed maturity by protecting the plants with insecticides at this time.

[1]The authors acknowledge the cooperation and assistance of the Beet Sugar Development Foundation in carrying on the field-cage studies in 1946 and 1947.

[2]U. S. Department of Agriculture, Agr. Res. Adm. Bureau of Entomology and Plant Quarantine.

[3]Numbers in parentheses refer to literature cited.

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# Plant Pathology

# Soil Fumigation Work in 1947

GERALD THORNE[1] AND VERNAL JENSEN[2]

SOIL FUMIGANTS were applied to about 700 acres of land prepared for sugar beets in the intermountain region in 1947, for the purpose of controlling the sugar beet nematode, *Heterodera schachtii* Schmidt. These applications were generally successful and satisfactory crops of sugar beets were produced on the majority of the fields. However, there were a few fields from which the yields fell far short of those anticipated and these failures again emphasize that soil fumigation is a technical process which must be carried out by well-equipped, competent operators, on soil which is in proper condition from the standpoint of tilth, moisture, temperature, and fertility. It is not at all surprising that occasional applications have been unsatisfactory when we consider that this was only the third year that field-scale fumigation has been practiced in this region, and certain technical aspects of the process still demand additional research. When we compare our success in soil fumigation with that of early work on insecticides and fungicides, it is evident that excellent progress has been made in the relatively brief period since commercially feasible products have been available.

Certain fumigated fields in the Lewiston, Utah, district presented the most serious problem experienced to date in the intermountain region. Applications were made from April 5 to 15 and immediately afterward about 3 inches of rain fell which, combined with the high water table of that section, practically submerged certain fields. As a result, 43 acres were classed as unsatisfactory and produced only an average of 12.9 tons of beets per acre. However, when we consider that these fields had produced beets in 1946 and were heavily infested with nematodes, these yields compare favorably with the district average of 13.0 tons per acre on untreated fields.

Unsatisfactory yields on these few fumigated fields of the Lewiston district doubtless were due to the excessive moisture content and lack of aeration of the soil. This is indicated by the fact that two fields in this general area, which were disked up and replanted after the flooding, because of poor stands, produced 15.5 and 17 tons per acre, respectively.

In contrast to the generally good results secured in the intermountain region there have been numerous reports of unsatisfactory yields from the fumigated fields in California. Apparently our success has largely been due to a combination of the following factors, one or more of which have not been applicable to the large-scale farming operations of that state:

1. Close supervision by the sugar company field men who have insisted that chemicals be applied only when fields are in proper condition.

[1]Nematologist, United States Bureau of Plant Industry, Soils and Agricultural Engineering, Salt Lake City, Utah.
[2]Research manager, Amalgamated Sugar Company, Ogden, Utah.

2. Small acreages which enable the owners to prepare them at the proper time and have them fumigated before excessive drying occurs.

3. High fertility of the fields after carefully planned crop rotations and the application of barnyard manure and commercial fertilizers.

4. Availability of applicators which make it possible to cover the fields at the proper time. Both chisel and plow-sole types of applicators have been built by the local sugar companies, generally on the growers' own tractors.

Typical of the yields secured from fumigation with 25 gallons of D-D per acre are the following data from the Smithfield, Utah, district:

| Crop succession | Acres | Tons per acre |
|---|---|---|
| Beet following beets | 6 | 19.4 |
| One year between beet crops | 3 | 22.0 |
| One year between beet crops | 6 | 17.0 |
| One year between beet crops | 1 | 20.0 |
| One year between beet crops | 8 | 20.0 |
| District average on untreated land | | 14.5 |

## Two Successive Sugar Beet Crops Produced with Fumigation

Two fields on which sugar beets have been grown 2 successive years following fumigation each year gave the following yields:

| Application | Tons per acre | | | |
|---|---|---|---|---|
| | Fumigated | | Untreated check | |
| | 1946 | 1947 | 1946 | 1947 |
| 25 gallons D-D per acre (No fertilizers applied in 1947) | 21.09 | 15.5 | 2.0 | 2.0 |
| Part 25 remainder 50 gallon D-D 1946, 25 gallon 1947 | 22.0 | 16.0 | 5.0 | 0 |

A check strip through the portion on which 50 gallons per acre were applied in 1946 was practically devoid of sugar beets, proving that even this heavy rate of application will give only 1 year of control of sugar beet nematodes on these old, severely infested fields.

## Comparative Experiments with D-D and Dowfume N

Data from fields which were fumigated, part with D-D and the remainder with Dowfume N, at the rate of 25 gallons per acre showed that these 1,3-dichloropropene mixtures are practically identical in their efficacy:

| Crop succession | Tons per acre | | |
|---|---|---|---|
| | DD | Dowfume N | Unfumigated check |
| Beets following 5 years alfalfa | 16.4 | 16.6 | 15.5 |
| Beets following beets | 19.79 | 19.79 | 6.0 |

It will be observed that approximately 1 ton per acre was added to the yield of the first field by fumigation, showing that even after long crop rotations there frequently is a considerable loss from surviving nematodes.

Beets from the untreated checks of the second field came largely from one end of the field where no nematodes were present, the infested portions being practically bare. Top growth of the beets on the fumigated areas was unusually vigorous and throughout the season there was a conspicuous difference between them and the tops of the uninfested portions of the check strips; an excellent demonstration of the "stimulation" frequently observed on fumigated soil. Sugar content of 5 samples, each containing 10 beets, from each of the 3 areas, gave 16.2 percent for both the D-D and Dowfume N and 15.4 percent for the untreated check.

### Comparative Yields from Crop Rotation and Fumigation

A field near Ogden, Utah, which was broken from alfalfa in 1945 was planted in 1946, part in sugar beets and the remainder in potatoes and corn. The beet yield was estimated at over 25 tons per acre. The entire field was planted in beets in 1947 after the 1946 beet portion was fumigated with 25 gallons of D-D per acre, except for a narrow check strip. Following are the 1947 yields:

| Crop succession | Tons per acre |
|---|---|
| Beets following alfalfa, potatoes and corn | 28.13 |
| Beets following beets after fumigation | 28.17 |
| Beets following beets, unfumigated check | 0 |

The excellent results secured during the first year following crop rotation are well illustrated in this field, while the futile attempt to produce a second crop without fumigation is demonstrated by the untreated check strip which was practically devoid of beets.

### Fumigation for Control of Sugar Beet Root Maggots and Root Aphids

A field severely infested with sugar beet root maggot, *Tetanops aldrichi* Hendl., and sugar beet root aphids, *Pemphigus betae* Doane, was fumigated with Dowfume W10 (10 percent by volume of ethylene dibromide in a petroleum thinner) at the rate of 25 gallons per acre. For this purpose a chisel-type applicator was used which had been adjusted to apply side-dressings of liquid fertilizers. The chemical was applied about 5 inches deep at a distance of 6 inches from each side of the row but, unfortunately, 25 gallons per acre were injected instead of the 20 gallons intended. The root maggots and aphids were completely killed out but considerable injury was caused to the beets roots, with an occasional plant dying. A lower dosage would probably have been just as efficient with less damage to the root system.

Chisel-type applicators mounted on the tool bars of tractors are ideal machines for applying liquid fertilizers like phosphoric acid and the residues from ion exchange batteries of the sugar factories. It may even be possible to apply some of the new insecticides mixed with the fertilizers for control of wire worms, white grubs and root-infesting insects as mentioned above, thereby making more extensive use of these machines.

# Observations on the Mechanics of Soil Fumigation

F. H. LEAVITT[1]

MUCH HAS BEEN SAID about the conditions under which soil fumigants can be effectively applied. You recall them all: tilth, well cultivated to 10 inches; moisture, ideal for seed germination; temperature, 35° to 85° F.; a minimum of undecomposed plant residue; apply at 12-inch spacing and 6 to 8 inches deep, using a railroad iron drag for sealing.

Perhaps, if we look closely at the soil, we may see why these factors are important.

Soil, and we shall speak primarily of mineral soil, is composed of particles ranging in size from small rocks down to minute particles, distinguishable only under a microscope. Soils composed primarily of large particles we call either gravel or a coarse sand. If the particles are primarily all very small, we call the soil a clay.

If we carefully scrutinize a handful of soil, we find that the particles fit together rather loosely and that there is between these particles a considerable open or pore space. The volume of this pore space varies from one soil to another. For a coarse sand, pore space is 35 percent; but for a clay, it may reach 53 percent. This means, of course, that in 1 cubic foot of sandy soil (1,728 cubic inches), 605 cubic inches is air space.

Now, if we could take all the particles in a cubic foot of sand and measure the surface area of them, we would find that it covered 8,318 square feet. If we used a cubic foot of clay, we would find that the surface area of all the particles totaled 173,900 square feet, or about 4 acres.

When soil is properly tilled, particles of the soil fit loosely together and, upon cleavage, will break apart into individuals rather readily if the soil is a sand or a sandy loam. If the soil is a fine-textured clay, the minute particles, sometimes as small as .0049 millimeters in diameter, or a little larger than a bacterium, will group themselves together into a crumb. Several hundred of them may combine into these crumbs, and even the crumbs may combine, forming clods; but under normal conditions these crumbs cleave one from another rather readily. If soil is worked too wet and under heavy pressure, the particles, either of a sand or of a clay, are mechanically compressed; and the irregular surfaces become interlocked, holding the particles together into a hard, compact clod. When this is done, the pore space of that soil is materially reduced.

[1]Senior Technologist, Shell Chemical Corporation, San Francisco, California.

Of course, soil is never completely dry. In it, there is always a certain amount of moisture, even when the soil may appear dry. This moisture is held not only in a thin film surrounding the points of contact between particles but is held also as imbibed moisture. This latter may be imbibed or it may actually be held in the cleavage plane spacing, according to the amount of moisture present. This latter accounts for the shrinkage and cracking of clays upon drying. If the soil is completely saturated, or waterlogged, all the pore space is filled with water and air is completely excluded. However, the soil under normal conditions will not long remain saturated, for gravity will remove the larger portion of the water, leaving again only a thin film of moisture around each particle or imbibed within the colloids. This water, removed by gravity, percolates slowly down through the soil to gravel strata, through which it may flow to natural stream drainage or to underground lakes.

If the sandy loam soil contained sufficient moisture to assure germination, there would be approximately 12 percent moisture present. This would be the equivalent of 6,700 cubic feet per acre foot of soil. In an acre foot of sandy loam, there would be 15,200 cubic feet of pore space. This, reduced by the 6,700 cubic feet of water, would still leave a total of 8,500 cubic feet of pore space. If we consider a clay loam soil or a clay, we would have approximately 25 percent moisture present for good seed germination. This would be 875,000 pounds of water, or 14,000 cubic feet of water. The pore space in a clay loam would amount to 23,200 cubic feet. From this let us deduct the volume occupied by the water; and we would find a total of 9,200 cubic feet of pore space remaining. It is interesting to note how closely the actual pore or air space in clay loam soils corresponds to the pore space in a sandy loam soil, when we consider the additional moisture present.

Temperature and temperature changes have a profound effect on soil. Of most interest to us is the movement of soil air under temperature changes. During the night, the air in soil is comparatively cold. In the morning, when the sun again reaches the soil, it warms slowly; and the cold air in the pore space gradually expands, forcing a portion of it out of the soil. Then, as evening comes, the air in the pore space contracts and fresh air is drawn in from the soil surface. We get, then, a sort of soil breathing that gradually circulates the soil atmosphere. During the winter months, these temperature changes are much less than during the summer; hence, a much slower air circulation takes place. This breathing, of course, changes the moisture content of the soil, depending upon the humidity of the air at the time air is drawn into the soil complex.

Let us consider now the injection of a soil fumigant into a soil in proper tilth and of proper moisture content. Injected at a depth of 6 inches, the fumigant volatilizes rather slowly. An application of 20 gallons of D-D completely volatilized yields 660 cubic feet of D-D vapor. (D-D, incidentally, is a registered trade-mark of Shell Chemical Corporation). This would fill but 6 percent of the pore space in an acre foot of

normal soil under a normal moisture content, or but 3 percent of the pore space if we consider, as we must, that we are fumigating at least 2 acre feet of soil.

If, now, we increase the amount of moisture present in either of these soils up to, or nearly to, complete saturation, there will be little opportunity for the penetration of the 660 cubic feet of D-D vapor present due to the pore passage blockage by the increased volume of water. We can expect, therefore, that the rate of D-D vapor penetration will not only be greatly reduced and the completeness of penetration limited but the effective control of the soil-borne organisms will be thereby influenced.

Let us now consider that we introduce into a well-tilled, moisture-free soil, sections of plant residue, corn stalks, roots, undecomposed cover crop, twigs, leaves, or such material. It can be seen that the contact between the soil particles and the portions of plant residue is not as firm as though only soil were present and that air or gas movement along the plant residue would be much less unimpeded than it would be through soil only. The interchange of vapor in soil full of plant debris would be, therefore, much more rapid than it would be in pure soil. If the residue lies at an angle and one end protrudes slightly above the surface of the soil, the twigs or sticks would act similar to a chimney and would tend to ventilate the soil much more rapidly. Moisture in the soil would change this factor but little and would still permit the very rapid movement of the soil fumigant, never permitting a lethal concentration of gas to build up, particularly along the surface of the plant residue.

Should we be working in soil of comparatively low temperature, down in the range of 32 to 35 degrees, then we could expect that the movement of the vapor within the soil between day and night would be comparatively low and that the dissemination of the D-D vapors through the soil pore space would be very, very slow. In fact, measurements made and reported by Mr. C. W. McBeth, Nematologist, Shell Agricultural Laboratory, Modesto, California, indicate that under low temperatures almost twice as long is taken before a lethal concentration of D-D can be built up. With the higher temperatures, 80 to 85 degrees, the difference between day and night temperature would cause a greater change of volume; consequently, a much more rapid movement of the D-D vapors through the soil; hence, a much more rapid kill. It might be well to point out at this point that, as the D-D vapor approaches the surface of the soil, say, the top inch, the rate of dissipation would be greatly increased due to the rapid movement of fresh air through the pore interstices due to temperature changes. It is, therefore, apparent that in this surface layer of 1 inch, toxic concentrations of D-D are much less likely to be built up. Fortunately, however, this surface layer usually is subject to alternate wetting and drying, which is favorable to the demise of nematodes.

Because of the fact that D-D must penetrate through the soil pore space, we do not believe it is advisable to space D-D applications wider than

12 inches apart, thus making it unnecessary for the D-D vapors to penetrate farther than necessary. It is advisable to adopt this arbitrary distance of 12 inches to assure that the D-D vapors penetrate easily from point of injection to point of injection.

The matter of soil sealing following a D-D application is one of utmost importance. One of our reasons for soil cultivation is the loosening of the soil to increase pore space as much as possible. When soil is of proper tilth for D-D application, this pore space is at a maximum. Following the D-D application, it is necessary to pull some sort of a tool over the ground to seal the shank channels left by the injection. When soil is moist, only a light drag should be used which will smear the surface of the soil or compact and force together in a compact, thin film only the upper soil particles. This will permit the D-D vapors to penetrate through the soil pore space up to the very surface of the soil. If, however, one uses a heavier roller, the surface of the soil is not only compacted but the entire soil mass is compacted, depending upon the weight of the roller used. This not only seals the soil but reduces the pore space of the soil, limiting the ability of the D-D to penetrate through it. There are conditions under which this may be advisable, but more data must be gathered before definite recommendations can be made. Let us assume, for instance, that we may be compelled to work in a comparatively dry, loose soil; and the case must be considered only one of hypothetical interest. If we make a D-D application under these conditions, we would expect rapid volatilization of the D-D and rapid movement through the soil pore spaces. If we then use a heavy roller, compact the mass as much as possible, thereby curtailing the movement of D-D somewhat, we can expect better control than would be achieved if the soil were left loose, dry, and open.

We have purposely left to the end of our discussion reference to undecomposed root materials present in soils at the time of soil fumigation. A considerable volume of experimental work has been done on such nematode-infested materials as potatoes and galls on undecomposed roots of alfalfa and trees or vines. While we have many reports that nematodes lying within undecomposed galls are killed, observations made on commercial applications indicate that larvae lying in potatoes or undecomposed galls are not killed and are left to reinfest soil when decomposition is completed after fumigation.

No time limit for decomposition of root materials can be given, and each job to be done must be carefully inspected in order that the state of residual root materials may be determined.

In orchards, it is not possible for root materials to decompose in less than a year; hence, it is not advisable to treat old deciduous or citrus orchard land until at least 1 year has elapsed from the time the trees were pulled. Then, too, tree roots lie deep, much deeper than fumigation can penetrate normally; and decomposition must be at least partial in order that the fumigant may follow along down the root channel, giving a maximum fumigation.

Frequently, following applications of D-D during winter months, unpredicted rains fall immediately after completion of the job. Besides limiting the effectiveness of the fumigation, the gases may be completely sealed in or absorbed in the soil moisture so as to remain undissipated for a long period of time. Under these conditions, it is advisable to insist on careful aeration of soils prior to planting. The best practice would be to plow again or at least disc to a depth of 8 to 10 inches. Should this be impossible and chiseling the only cultivation given, insist on at least chiseling both ways.

Listing prior to bed planting will also be sufficient to properly aerate soils.

# Spray Treatment of Sugar Beet Seed

L. D. Leach[1]

Most plantings of sugar beets would result in satisfactory stands even though no seed treatments were used. In those cases, however, where damping-off is severe, seed treatment with fungicides will often produce spectacular improvements in stand and may eliminate the necessity for replanting. This protection is particularly important when reduced seeding rates are used.

In the past most seed treatment has consisted of dusting the seed with a fungicide during agitation in either a continuous or a batch treater. This operation has not been entirely satisfactory chiefly because the dusts are offensive to the operator during treating and to the grower during planting. Some of the fungicides are poisonous when ingested, others cause severe skin irritation particularly upon susceptible individuals while others are offensive when inhaled.

A method of treating that would eliminate dustiness but at the same time would be simple in operation, effective and non-injurious to seed germination would be highly desirable.

Among the methods that have been used for eliminating dustiness are: 1.—dusting the seed with a dry fungicide and then spraying it with a soluble sticker, and 2.—application of a suspension of a wettable fungicide by means of a "Slurry" treater.

The first method was used by P. Vogelsang and P. A. Reeve of the Farmers and Manufacturers Beet Sugar Association for the preparation of samples for the 1946 and 1947 cooperative beet seed treatment tests.[2] A very acceptable product resulted and tests showed that the protection was fully equal to the same dosages applied as dusts. This method, however, involves two separate operations and does not eliminate the dust problem during the first step of treatment.

The slurry method and the slurry treater were developed by E. I. du Pont de Nemours and Company. The suspension of a wettable fungicide is smeared over the surface of the seeds in a mixing chamber with so little liquid that drying is unnecessary. This process eliminates all dustiness except during the preparation of the suspension. With smooth seed like corn, peas, beans or milo, a uniform coating is formed over the seeds. With sugar beet seed, however, the corky surface is so rough and absorbent that the small amount of suspension ordinarily applied does not seem to provide a uniform covering. Tests on the comparative protection afforded by dust and slurry treatment of sugar beet seed are insufficient to draw definite conclusions.

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[1]Plant Pathologist, California Agricultural Experiment Station, Davis, California.

[2]Conducted by The Beet Sugar Development Foundation. Cooperative Seed Treatment Committee, A. R. Downie, Chairman.

Spraying the seed with a suspension of a wettable fungicide or with a soluble fungicide while the seed is being agitated in a revolving drum affords still another method of eliminating dustiness from the seed-treating process.

Preliminary trials indicated that a suspension of a wettable fungicide applied at from 2 to 4 percent of the seed weight provided protection equal to a dust treatment. This method eliminated dustiness and resulted in a product that could be planted satisfactorily without drying. Utilizing this principle Armer (1) of the Spreckels Sugar Company designed and built a semi-automatic batch treater for applying, by means of spray nozzles, suspensions of wettable fungicides in water together with an adhesive, water-soluble binder.

Numerous tests have been conducted under greenhouse conditions in both pasteurized and infested soils to compare the protective effects and safety of commercial and experimental fungicides at different dosages. The results of some of these tests as well as comparisons of treating methods are presented in the following tables.

### Comparison of Dust and Slurry Treatments

Seed of variety U. S. 33 was treated with suspensions containing Arasan SF (75 percent tetramethyl thiuramdisulfide), Ceresan M (7.7 percent ethyl mercury p-toluene sulphonanilide) and Wettable Phygon (dichloro-naphthoquinone). These suspensions were applied to the seed by mixing the seed and slurry in a revolving can using liquid equal to 2.5 percent of the seed weight. Samples of the three slurry-treated lots, seed treated with Phygon dust and non-treated seed were planted in randomized rows in soil infested with *Pythium ultimum* Trow. The emergence and survivors are reported in table 1.

**Table 1.**—Slurry and dust treatment of sugar beet seed.

| Treatment | Method | Dosage (percent) | Emergence per 100 seed units | Survivors per 100 seed units |
|---|---|---|---|---|
| Non treated | ---- | --- | 111.5 | 46.0 |
| Arasan SF | Slurry | 0.67 | 103.5 | 65.5 |
| Ceresan M | Slurry | 0.375 | 142.5 | 128.5 |
| Phygon | Slurry | 1.00 | 139.0 | 100.5 |
| Phygon | Dust | 1.00 | 142.0 | 107.0 |

The results indicate that the protection from a Phygon slurry is approximately equal to that afforded by a Phygon dust treatment. Ceresan M gave somewhat better and Arasan SF somewhat poorer protection under the conditions of this test. Another investigator who tested samples of the same lots reported as good protection from Arasan as from the other fungicides. In this trial the treatment was not applied in a commercial slurry treater and the results, therefore, provide no measure of coverage by such equipment.

### Comparison of Spray and Dust Treatments

When applied as a spray, Wettable Phygon with a binder (Armer's formula) gave about the same protection as the same fungicide applied as a dust (table 2) and was about as effective as Ceresan (ethyl mercury chloride) applied as a dust.

**Table 2.**—Comparative protection of spray and dust seed treatments on sugar beets planted in infested soil.

| Treatment | Emergence per 100 seed units | Survivors per 100 seed units |
|---|---|---|
| Non treated | 41.5 | 13.5 |
| Phygon spray[1] | 105.5 | 93.5 |
| Phygon dust[2] | 105.0 | 92.0 |
| Ceresan dust[2] | 111.0 | 101.5 |

[1]Wettable Phygon 1 pound in 2 quarts of liquid (consisting of 1/3 molasses and 2/3 water) per 100 pounds of seed.
[2]Dosage 1 pound of dust per 100 pounds of seed.

In another set of tests, spray applications of Arasan SF and Wettable Phygon at three dosages were compared with dust applications of Arasan, Phygon and New Improved Ceresan (ethyl mercury phosphate).

All of the fungicidal applications shown in table 3 improved emergence and survival as compared to non-treated seed. Protection was improved with each fungicide as dosages were increased.

**Table 3.**—Comparison of dust and spray seed treatments.

| Treatment | Method | Dosage (percent) | Seedlings per 100 seed units | | Disease rating |
|---|---|---|---|---|---|
| | | | Emergence[1] | Survivors | |
| Non treated | --- | --- | 48 | 24 | 73.3 |
| Arasan SF | Spray | 0.22 | 86 | 58 | 48.9 |
| Arasan SF | Spray | 0.44 | 107 | 81 | 34.5 |
| Arasan SF | Spray | 0.88 | 112 | 84 | 31.6 |
| Arasan | Dust | 1.00 | 127 | 108 | 19.6 |
| Phygon | Spray | 0.22 | 92 | 69 | 43.8 |
| Phygon | Spray | 0.44 | 114 | 96 | 28.0 |
| Phygon | Spray | 0.88 | 123 | 93 | 24.7 |
| Phygon | Dust | 1.00 | 122 | 107 | 22.0 |
| N. I. Ceresan | Dust | 0.25 | 130 | 102 | 19.6 |
| Significant difference | 19:1 Odds | | 22.5 | 20.4 | |

[1]Potential emergence 150 seedlings per 100 seed units.

The disease rating (last column) was obtained by comparing emergence and survival with the potential emergence of this seed lot, giving twice as much weight to pre-emergence damping-off as to post-emergence infection. This difference was made because in the writer's opinion greenhouse conditions are relatively much more favorable to post-emergence infection than are ordinary field conditions.

At the highest dosages used the three materials were about equally effective and considering the severity of infection, all except the lowest dosages of Arasan and Phygon gave satisfactory protection. The seed used in this trial was variety U. S. 15 and carried a moderate amount of seed-borne *Phoma betae* (Oud.) Frank.

Additional comparisons of the protection afforded by different dosages of Arasan SF, Wettable Phygon and Ceresan M are presented in table 4. Trial 1 was conducted in less heavily infested soil than trials 2 and 3 and, therefore, direct comparisons between the three materials cannot be made. With Arasan and Phygon the protection improved as the dosage increased although the differences between the two higher dosages were not great. With Ceresan M a dosage of 0.25 percent appeared to delay and reduce emergence although the protection was good. With this material, applied as a spray, additional trials and storage experiments are required before its safety can be determined.

**Table 4.** Dosage relations with three fungicides in spray applications.

| Treatment | Dosage (percent) | Emergence[1] | Survivors[1] | Disease rating |
|---|---|---|---|---|
| Trial 1 | | | | |
| Non treated | --- | 53 | 7 | 65 |
| Arasan SF | 0.15 | 74 | 42 | 40 |
| Arasan SF | 0.30 | 80 | 68 | 29 |
| Arasan SF | 0.60 | 88 | 71 | 23 |
| Significant difference | 19:1 Odds | 19.8 | 18.8 | -- |
| Trial 2 | | | | |
| Non treated | --- | 6 | 1 | 96 |
| Phygon (W) | 0.22 | 70 | 30 | 48 |
| Phygon (W) | 0.44 | 96 | 49 | 25 |
| Phygon (W) | 0.88 | 97 | 59 | 21 |
| Significant difference | 19:1 Odds | 20.3 | 17.0 | -- |
| Trial 3 | | | | |
| Non treated | --- | 6 | 1 | 96 |
| Ceresan M | 0.06 | 65 | 15 | 55 |
| Ceresan M | 0.12 | 86 | 54 | 30 |
| Ceresan M | 0.25 | 76 | 67 | 32 |
| Significant difference | 19:1 Odds | 23.6 | 13.6 | -- |

[1]Seedlings per 100 seed units; potential emergence—107 seedlings per 100 seed units.

When the three materials were compared in heavily infested soils (table 5) Arasan SF did not appear to be as effective as Wettable Phygon or Ceresan M at the dosages compared in three trials.

**Table 5.**—Protection afforded by three fungicides in spray applications.

| Treatment | Dosage (percent) | Trial 1 Disease rating | Trial 2 Disease rating | Trial 3 Disease rating |
|---|---|---|---|---|
| Non treated | --- | 96 | 98 | 91 |
| Arasan SF | 0.30 | -- | -- | 82 |
| Arasan SF | 0.60 | 71 | 68 | -- |
| Phygon (W) | 0.44 | -- | -- | 46 |
| Phygon (W) | 0.88 | 23 | 48 | -- |
| Ceresan M | 0.12 | -- | -- | 36 |
| Ceresan M | 0.25 | 32 | 35 | -- |

As a further test of the spray application of suspension of wettable fungicides, seed lots of 50 pounds each were treated with three dosages of Wettable Phygon and with two dosages of Arasan SF all applied in Armer's spray treater. Emergence and survival of seedlings in Pythium infested soil (table 6) indicate that all three dosages of Phygon gave good protection with the highest dosage slightly better than the others. Arasan SF in trial 2 also provided considerable protection but was somewhat less effective than the same dosages of Phygon.

**Table 6.**—Protection afforded by applying Phygon and Arasan to beet seed with the Spreckels Spray Treater.

| Treatment | Dosage (percent) | Trial 1 | | Trial 2 | |
|---|---|---|---|---|---|
| | | Emergence[1] | Survivors[1] | Emergence[1] | Survivors[1] |
| Non treated | --- | 26 | 9 | 30 | 15 |
| Phygon | 0.50[2] | 96 | 76 | 89 | 75 |
| Phygon | 0.75 | 96 | 76 | -- | -- |
| Phygon | 1.00 | 111 | 87 | 94 | 76 |
| Arasan SF | 0.50 | -- | -- | 62 | 41 |
| Arasan SF | 1.00 | -- | -- | 79 | 55 |
| Significant difference | 19:1 Odds | 12.1 | 13.1 | 16.2 | 18.1 |

[1]Seedlings per 100 seed units; potential emergence 124.
[2]Applied in a suspension equivalent to 4 percent of the seed weight.

## Summary

One of the most objectionable features in the treatment of sugar beet seed is the offensive nature of the fungicidal dusts now in use. Some are poisonous when ingested, others cause severe skin irritation to susceptible individuals while others are irritating when inhaled.

Dustiness can be reduced or avoided by spraying the seed with a soluble binder after it has been dusted or by treating the seed by the slurry method. Using equipment currently available, however, the slurry treatment does not appear to provide uniform seed coverage because of the rough and absorbent surface of sugar beet seed.

It has been found that good coverage and complete elimination of dustiness can be obtained by spraying soluble fungicides or water suspensions of wettable fungicides with a suitable binder through nozzles onto seed during agitation in a rotating container. Sugar beet seed treated in this manner was protected against damping-off as effectively as by the same materials in dust form. Spray treated seed could be planted through precision planters since the small amount of moisture applied either evaporated or was absorbed into the seedballs.

In moderately infested soils, seed treated by the spray method with either Arasan SF, Wettable Phygon or Cerasan M was adequately protected. The degree of protection with Arasan SF and Phygon increased as the dosage was increased up to 1.0 percent although the difference between 0.5 and 1.0 percent was not great. With Cerasan M the spray application gave excellent protection but indications of retarded emergence were

obtained in one trial at 0.25 percent dosage. In heavily infested soil, Phygon and Cerasan M applied as sprays or New Improved Cerasan applied as a dust gave somewhat better protection than Arasan in some of the trials.

Spray application of a wettable fungicide in suspension or of a soluble fungicide appears to be an effective method of treating sugar beet seed and in addition eliminates dustiness, the most objectionable feature of dust seed treatments.

## Literature Cited

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1948. A mechanical spray treater for sugar beet seed. Proc. Amer. Soc. Sugar Beet Technologists. Page 108.

# Effect of Seed Treatments on Seedling Diseases of Beets Planted in the Greenhouse in Highly Infested Soil[1]

M. M. Afanasiev

Various chemical compounds, in different combinations and concentrations were used for treating sheared sugar beet seed for controlling seedling diseases of beets. The following chemicals were used: New Improved Ceresan, Ceresan, Yellow cuprocide, Phygon, Arasan, Copper trichlor phenate and Chloranil. These were used either in the form of dust or the chemical materials were stuck on the seed by the use of Methocel In addition to these chemicals, 10 percent of treble-superphosphate was added to some of this seed. Some seed was also pelleted and the treating chemicals were incorporated in the pelleting material. Two separate experiments were conducted.

The seed used in these experiments was U. S. 215x216 beet variety and was furnished by the Beet Sugar Foundation of Fort Collins, Colorado. The treatments were designed by the Committee on Seed Treatments of the American Society of Sugar Beet Technologists. The Farmer's and Manufacturer's Beet Sugar Association of Saginaw, Michigan, arranged to treat this seed. All fungicides, treble-phosphate, etc., are given in percentage of weight of seed. The treated seed for the first experiment was distributed directly by the Farmer's and Manufacturer's Beet Sugar Association, and the seed for the second experiment was distributed by Dr. A. R. Downie, Chairman of the Committee on Seed Treatments.

The seed of the first experiment was treated as indicated in table 1. Untreated seed of beet variety Arizona 59 was planted as an additional check in soil fertilized with nitrogen, phosphorus and manure. The experiment was repeated using the same soil.

The seed of the second experiment was treated as indicated in table 2. An additional check was used where untreated seed of U. S. 215x216 was planted in soil fertilized with nitrgoen, phosphorus and manure.

An 8 percent solution of Methocel was used as a binding material for making pellets. Six quarts of this solution were used per 15 pounds of seed. The inert material in the pellets consisted of 2/3 feldspar and 1/3 fly-ash. The fly-ash was produced by burning powdered coal. The pellets were built up in a rotating drum. For pasting the different fungicides and treble-superphosphate on the seeds the same solution of Methocel was used as above, except that only 2.5 quarts of this solution were used per each 15 pounds of seed.

[1]Contribution from Montana State College, Botany and Bacteriology Department, Agricultural Experiment Station, Paper No. 202, Journal Series.

These tests were conducted in the greenhouse. Soil from the third year of the alfalfa plot in rotation 62B at the Huntley Branch Station, Huntley, Montana, was used in the greenhouse-flats which held 24 pounds of soil. A high percentage of seedling disease always occurred in this soil in previous studies. For each treatment, three rows of sheared sugar beet seed, each containing 40 seeds, were planted in each flat. The following fertilizers were added to one of the check flats in both experiments: 15.7 grams of sodium nitrate, 1.8 grams of treble-superphosphate and 1/5 of manure on the basis of soil volume.

Regular readings of healthy and diseased plants were taken approximately for 1 month after emergence. At the end of this period the plants in all flats were harvested and final readings pertaining to the amount of disease and weight of seedlings were taken.

## Results and Discussion

Two consecutive plantings of the seed of the first experiment were made in the same soil. The percentage of healthy seedlings for the treated seed in the first planting (table 1) varied between 7.7 (1.0 percent of Arasan with Methocel) and 42.6 (1.0 percent of Phygon with Methocel) and in the second planting between 0.0 and 1.0 (1.0 percent of Phygon dust). Check seed planted in non-fertilized soil had 20.8 percent of healthy seedlings in the first planting and none in the second planting. Untreated seed planted in fertilized soil had 98.4 percent healthy seedlings in the first planting and 92.2 percent in the second planting. These results show that there was a considerable decrease in the percentage of healthy beet seedlings in the second planting as compared to the first one. Apparently an accumulative effect of the inoculum had something to do with this situation.

The results of the second experiment show (table 2) that the percentage of healthy seedlings grown from all treated seed was very low and varied between none and 1.3 percent (5 percent of Arasan, 2.5 percent of Phygon, 0.25 percent of Ceresan and 10 percent of treble-superphosphate) for individual treatments. Untreated seed planted in unfertilized soil had no healthy seedlings and similar seed planted in fertilized soil had 97.1 percent of healthy seedlings.

These results show that the effect of all seed treatments used in controlling seedling diseases of sugar beets was very small. Untreated beet seed planted at the same time in fertilized soil produced a large number of healthy seedlings. It is evident that any fertilization which produces vigorous, fast-growing beets was more important in controlling seedling diseases of beets than the different seed treatments in these experiments. The weights of beets grown in fertilized soil were in most cases much higher than those grown from treated or untreated seed planted in unfertilized soil. These results confirm those obtained in previous investigations. Seedling diseases of sugar beets are complex in nature, but under Montana conditions *Aphanomyces cochlioides* is perhaps the most important organism responsible for seedling diseases of sugar beets.

**Table 1.**—Effect of seed treatments on seedling diseases of sugar beets under greenhouse conditions, Bozeman, Montana, 1947.

| | First Planting | | | | | | Second planting | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | At harvest | | | | | | | | | | | At harvest |
| | Sugar beet seedlings | | | | Weight per plant | | Sugar beet seedlings | | | | Weight per plant | |
| | Number | | Percent | | Grams | | Number | | Percent | | Grams | |
| Seed treated with | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased |
| 0.375[1] percent N.I. Ceresan Methocel | 10 | 102 | 8.9 | 91.1 | 0.62 | 0.47 | 0 | 88 | 0.0 | 100.0 | 0.00 | 0.11 |
| 1.0 percent Y. Cuprocide Methocel | 17 | 86 | 16.5 | 83.5 | 0.88 | 0.46 | 0 | 99 | 0.0 | 100.0 | 0.00 | 0.08 |
| 1.0 percent Phygon dust | 17 | 103 | 14.2 | 85.8 | 0.74 | 0.61 | 1 | 99 | 1.0 | 99.0 | 0.10 | 0.09 |
| 1.0 percent Phygon Methocel | 43 | 58 | 42.6 | 57.4 | 1.83 | 1.20 | 0 | 95 | 0.0 | 100.0 | 0.00 | 0.25 |
| 1.0 percent Arasan dust | 21 | 91 | 18.7 | 81.3 | 1.31 | 1.47 | 0 | 98 | 0.0 | 100.0 | 0.00 | 0.14 |
| 1.0 percent Arasan Methocel | 8 | 96 | 7.7 | 92.3 | 0.50 | 0.71 | 0 | 92 | 0.0 | 100.0 | 0.00 | 0.11 |
| Check | 15 | 57 | 20.8 | 79.2 | 1.60 | 2.21 | 0 | 83 | 0.0 | 100.0 | 0.00 | 0.14 |
| Check + NPM | 124 | 2 | 98.4 | 1.6 | 0.79 | 0.20 | 107 | 9 | 92.2 | 7.8 | 1.08 | 0.13 |

[1]All fungicides, treble-superphosphate, etc., are given in percentage of weight of seeds.

**Table 2.**—Effect of seed treatments on seedling diseases of sugar beets under greenhouse conditions, Bozeman, Montana, 1947.

| | | Sugar beet seedlings | | | | At harvest weight per plant | |
|---|---|---|---|---|---|---|---|
| | | Number | | Percent | | Grams | |
| Code No. | Seed treated with | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased |
| | Untreated sheared seed 7/64" — 9/64" | 0 | 147 | 0.0 | 100.0 | 0.0 | 0.10 |
| 4701X | 3/8[1] percent New Improved Ceresan | 0 | 145 | 0.0 | 100.0 | 0.0 | 0.13 |
| 4702X | 1 percent Phygon, 10 percent T.S.P.[2] | 1 | 156 | 0.6 | 99.4 | 0.1 | 0.14 |
| 4703X | 2½ percent Phygon, 10 percent T.S.P. | 0 | 150 | 0.0 | 100.0 | 0.0 | 0.21 |
| 4704X | 5 percent Phygon, 10 percent T.S.P. | 0 | 153 | 0.0 | 100.0 | 0.0 | 0.18 |
| 4705X | 1 percent Arasan, 10 percent T.S.P. | 0 | 167 | 0.0 | 100.0 | 0.0 | 0.15 |
| 4706X | 5 percent Arasan, 10 percent T.S.P. | 0 | 164 | 0.0 | 100.0 | 0.0 | 0.18 |
| 4707X | 10 per cent Arasan, 10 percent T.S.P. | 0 | 138 | 0.0 | 100.0 | 0.0 | 0.17 |
| 4708X | ¼ percent Cu Trichlor phenate, 10 percent T.S.P. | 0 | 127 | 0.0 | 100.0 | 0.0 | 0.34 |
| 4709X | 1 percent Cu Trichlor phenate, 10 percent T.S.P. | 0 | 122 | 0.0 | 100.0 | 0.0 | 0.34 |
| Pellet 808 | 5 percent Arasan, 5 percent Cuprocide, 5 percent Chloranil, 10 percent T.S.P. | 0 | 127 | 0.0 | 100.0 | 0.0 | 0.27 |
| 4710X | 5 percent Arasan, 5 percent Cuprocide, 5 percent Chloranil, 10 percent T.S.P. | 2 | 157 | 1.3 | 98.7 | 0.05 | 0.15 |
| Pellet 907 | 5 percent Arasan, 2½ percent Phygon, ¼ percent Ceresan, 10 percent T.S.P. | 0 | 127 | 0.0 | 100.0 | 0.0 | 0.26 |
| 4711X | 5 percent Arasan, 2½ percent Phygon, ¼ percent Ceresan, 10 percent T.S.P. | 0 | 153 | 0.0 | 100.0 | 0.0 | 0.15 |
| Pellet | 10 percent Arasan, 10 percent T.S.P. | 0 | 128 | 0.0 | 100.0 | 0.0 | 0.15 |
| | Untreated sheared seed + NPM | 135 | 4 | 97.1 | 2.9 | 4.7 | 1.00 |

[1]All fungicides, treble-superphosphate, etc., are given in percentage of weight of seeds.
[2]T.S.P. = treble-superphosphate.

# Cooperative Beet Seed Treatment Tests, 1947

A. R. Downie[1]

An increasing number of chemical materials for seed treatment are being placed on the market every year. There is a need for definite information to serve as a guide to processing companies and to growers, as to the treatments apt to produce best results. The American Society of Sugar Beet Technologists appointed a Committee on Seed Treatments to investigate this subject.

A test was designed including 14 seed treatments and the untreated check. The US 215x216 variety was used, being sheared and sized to 7/64- to 9/64-inch segments and with an initial laboratory germination of 90 percent. The seed treatments were all applied in the Dow Chemical Laboratory at Midland, Michigan, under the supervision of Dr. Phelps Vogelsang and Perc Reeve, both being members of the Seed Treatment Committee.

Each test consisted of 6 replications of 120 seeds per row for each of the 15 variables. The tests were run in cooperation with the research staffs of the various sugar companies, with members of the Sugar Plants Office of the United States Department of Agriculture, and with members of the experiment station staffs of a few state universities located in the beet-growing areas. Seventeen tests were carried to completion. The location of these tests and the cooperating agencies are listed in table 1.

**Table 1.—Locations of cooperative seed-treatment tests and the cooperating agencies for 1947.**

| Test Number | Location of Test | Cooperating Agency |
|---|---|---|
| 1 | Jerome, Idaho | Amalgamated Sugar Company |
| 2 | Rocky Ford, Colorado | American Crystal Sugar Company |
| 3 | Mason City, Iowa | American Crystal Sugar Company |
| 4 | Chaska, Minnesota | American Crystal Sugar Company |
| 5 | East Grand Forks, Minnesota | American Crystal Sugar Company |
| 6 | Billings, Montana | Great Western Sugar Company |
| 7 | Longmont, Colorado | Great Western Sugar Company |
| 8 | Longmont, Colorado | Great Western Sugar Company |
| 9 | Saginaw, Michigan | Farmers & Manufacturers Beet Sugar Association |
| 10 | Sheridan, Wyoming | Holly Sugar Corporation |
| 11 | Fort Collins, Colorado | Beet Sugar Development Foundation |
| 12 | Beltsville, Maryland | Sugar Plants Office, USDA |
| 13 | Fort Collins, Colorado | Sugar Plants Office, USDA |
| 14 | Scottsbluff, Nebraska | Sugar Plants Office, USDA |
| 15 | Huntley, Montana | Montana State College |
| 16 | Mitchell, Nebraska | University of Nebraska |
| 17 | Davis, California | University of California |

Since it is almost impossible to conduct such a widespread test using all of the seed-treatment chemicals currently being offered to the public, the Committee selected the treatments shown in table 2. All percentage figures listed in this table are in comparison to the weight of seed.

[1]Plant Pathologist, American Crystal Sugar Company, Rocky Ford, Colorado. Chairman, Seed Treatment Committee, American Society of Sugar Beet Technologists.

Table 2.—Treatments in cooperative seed-treatment test, 1947.

| Number | Seed Treatment |
|---|---|
| 1 | Untreated sheared seed 7/64- to 9/64" |
| 2 | 3/8 percent New Improved Ceresan, no Superphosphate |
| 3 | 1 percent Phygon, 10 percent Treble-superphosphate |
| 4 | 2½ percent Phygon, 10 percent Treble-superphosphate |
| 5 | 5 percent Phygon, 10 percent Treble-superphosphate |
| 6 | 1 percent Arasan, 10 percent Treble-superphosphate |
| 7 | 5 percent Arasan, 10 percent Treble-superphosphate |
| 8 | 10 percent Arasan, 10 percent Treble-superphosphate |
| 9 | ¼ percent Cu Trichlor phenate, 10 percent treble-superphosphate |
| 10 | 1 percent Cu Trichlor phenate, 10 percent treble-superphosphate |
| 11[1] | 5 percent Arasan, 5 percent Cuprocide, 5 percent Chloranil, 10 percent treble-superphosphate |
| 12 | 5 percent Arasan, 5 percent Cuprocide, 5 percent Chloranil, 10 percent treble-superphosphate |
| 13[1] | 5 percent Arasan, 5 percent Cuprocide, 5 percent Chloranil, 10 percent treble-superphosphate |
| 14 | 5 percent Arasan, 2½ percent Phygon, ¼ percent Ceresan, 10 percent treble-superphosphate |
| 15[1] | 10 percent Arasan, 10 percent treble-superphosphate |

[1]Seed pelleted with Flyash-Feldspar carrier.

All chemicals, except in the case of treatment 2, were stuck to the seed with Methocel. Treatment 2 was a straight dust treatment, with the thought that it might serve as more or less a standard for comparison with the other treatments.

## Results

Nine of the 17 tests resulted in significantly better stands due to one or more of the treatments. In table 3 are listed the average number of seedlings obtained from 120 seeds planted in 6 replications for each treatment and also the grand average for all of the 9 tests.

Twelve of the 14 treatments resulted in significantly better stands than the untreated seed at Beltsville, Maryland. In contrast, only one treatment was significantly better than untreated seed at Huntley, East Grand Forks, Mason City, Fort Collins, and Saginaw.

The averages of each treatment for all nine locations in table 3 reveal some interesting comparisons. The averages of treatments 9 and 10 are the lowest and third lowest, respectively. Both of these treatments contained copper trichlorphenate. The addition of flyash-feldspar carrier for pelleting resulted in reduced stands in the treatment 13 and 14 comparisons. There was also a tendency for reduced stands in the treatment 15 and 8 comparison, while the stands in the treatment 11 and 12 comparisons were essentially the same.

It is of interest to note, although there is not too much spread between the highest and lowest average stand for the nine tests, that the four (treatments 14, 7, 12 and 11) highest average stands all contain 5 percent Arasan either alone or in combination with other fungicides.

Table 3.—Cooperative seed-treatment tests resulting in significantly better stands than untreated seed, 1947.

| Treatment Numbers | Location of tests—Stand counts according to treatment numbers | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Beltsville, Maryland | Scottsbluff, Nebraska | Sheridan, Wyoming | Jerome, Idaho | Mason City, Iowa | E.G.F., Minnesota | Saginaw, Michigan | Ft. Collins, Colorado | Huntley, Montana | Average of nine tests |
| 1 | 50.9 | 49.0 | 43.6 | 29.8 | 81.8 | 78.0 | 66.2 | 97.3 | 69.2 | 62.8 |
| 2 | 64.1 | 81.0[1] | 52.0 | 12.8 | 85.5 | 79.0 | 72.7 | 100.6 | 83.3[1] | 70.1 |
| 3 | 88.8[1] | 50.0 | 52.3 | 19.3 | 85.2 | 81.2 | 70.8 | 103.6 | 69.7 | 69.0 |
| 4 | 86.0[1] | 67.0[1] | 47.5 | 15.8 | 83.8 | 87.6 | 71.2 | 87.3 | 63.2 | 67.7 |
| 5 | 86.7[1] | 58.0 | 53.1[1] | 17.8 | 81.2 | 77.9 | 62.7 | 94.3 | 69.6 | 66.8 |
| 6 | 79.0[1] | 53.0 | 58.5[1] | 35.0 | 80.0 | 85.3 | 57.0 | 100.3 | 61.8 | 67.8 |
| 7 | 80.3[1] | 66.0[1] | 54.6[1] | 31.4 | 88.8 | 85.7 | 82.8[1] | 95.1 | 71.2 | 72.9 |
| 8 | 88.1[1] | 61.0[1] | 60.0[1] | 26.7 | 87.8 | 83.3 | 73.5 | 97.1 | 62.9 | 71.2 |
| 9 | 64.7 | 47.0 | 38.5 | 37.4 | 76.3 | 66.4 | 53.8 | 68.1 | 63.2 | 57.3 |
| 10 | 83.3[1] | 70.0[1] | 39.0 | 35.0 | 75.5 | 69.7 | 53.8 | 74.1 | 62.7 | 62.6 |
| 11 | 114.4[1] | 36.0 | 47.6 | 41.8 | 95.5[1] | 76.7 | 56.8 | 113.3[1] | 66.6 | 72.1 |
| 12 | 90.1[1] | 69.0[1] | 50.7 | 32.7 | 85.7 | 86.3 | 70.5 | 89.0 | 77.7 | 72.4 |
| 13 | 96.9[1] | 60.0 | 26.5 | 41.2 | 67.3 | 70.6 | 51.7 | 95.1 | 51.5 | 62.3 |
| 14 | 100.4[1] | 54.0[1] | 48.6[1] | 43.7[1] | 81.8 | 92.0[1] | 79.2 | 93.1 | 77.5 | 76.6 |
| 15 | 100.8[1] | 56.0 | 56.8[1] | 43.7[1] | 80.0 | 75.9 | 60.8 | 96.6 | 51.5 | 69.1 |
| Mean | 85.3 | 59.0 | 49.0 | 31.4 | 81.7 | 80.0 | 65.6 | 94.6 | 67.0 | |
| Difference required for significance | 15.1 | 11.7 | 9.5 | 12.4 | 13.5 | 33.4 | 16.3 | 14.0 | 11.3 | |

[1]Significantly better than untreated seed at the 5-percent level of significance.

**Table 4.**—Cooperative seed-treatment tests not resulting in significantly better stands than untreated seed, 1947.

| Treatment numbers | Location of tests—Stand counts according to treatment numbers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rocky Ford, Colorado | Longmont, Colorado | Longmont, Colorado | Ft. Collins, Colorado | Mitchell, Nebraska | Billings, Montana | Davis, California | Chaska, Minnesota | Average of eight tests |
| 1 | 41.2 | 65.3 | 66.3 | 88.3 | 52.6 | 83.3 | 45.0 | 105.0 | 68.4 |
| 2 | 48.3 | 65.0 | 67.0 | 82.3 | 62.1 | 75.5 | 47.5 | 94.0 | 67.7 |
| 3 | 37.0 | 62.7 | 63.5 | 75.2 | 61.1 | 78.2 | 46.7 | 90.0[1] | 64.3 |
| 4 | 42.3 | 61.5 | 70.5 | 77.2 | 54.3 | 89.0 | 47.2 | 91.0[1] | 66.6 |
| 5 | 46.6 | 56.8 | 68.8 | 62.0[1] | 55.4 | 78.0 | 40.8 | 77.0[1] | 60.7 |
| 6 | 42.2 | 59.7 | 68.7 | 74.8 | 56.9 | 77.5 | 57.5 | 89.0[1] | 65.8 |
| 7 | 51.3 | 71.0 | 71.2 | 83.2 | 63.2 | 88.3 | 49.2 | 79.0[1] | 69.6 |
| 8 | 31.7 | 71.0 | 69.2 | 81.2 | 55.3 | 88.0 | 57.3 | 90.0[1] | 68.0 |
| 9 | 37.5 | 48.3[1] | 61.0 | 72.2[1] | 59.8 | 77.2 | 37.8 | 78.0[1] | 59.0 |
| 10 | 33.2 | 57.5 | 58.2 | 59.5[1] | 53.1 | 69.4 | 45.2 | 74.0[1] | 56.3 |
| 11 | 59.6 | 49.7[1] | 68.5 | 71.5[1] | 60.8 | 88.0 | 53.7 | 99.0 | 68.8 |
| 12 | 50.9 | 53.8 | 61.7 | 73.7[1] | 51.0 | 89.5 | 44.3 | 93.0[1] | 64.7 |
| 13 | 38.3 | 59.0 | 61.2 | 52.2[1] | 47.8 | 70.1 | 42.5 | 79.0[1] | 56.3 |
| 14 | 46.3 | 61.0 | 69.3 | 79.5 | 51.0 | 71.9 | 44.7 | 89.0[1] | 64.1 |
| 15 | 32.9 | 64.3 | 63.3 | 62.7[1] | 57.4 | 80.8 | 52.2 | 95.0 | 63.6 |
| Mean | 42.8 | 60.4 | 65.9 | 72.0 | 56.3 | 80.6 | 47.4 | 88.2 | |
| Difference require for significance | NS | 11.8 | NS | 14.5 | NS | NS | NS | 11.5 | |

[1]Significantly less stand than untreated seed at 5-percent level of significance.

Eight of the 17 tests resulted in no significant increase due to seed treatment. The results for these tests are presented in table 4. Three of these tests resulted in reduced stands due to treatments. In the test at Chaska, Minnesota, 11 of the 14 treatments resulted in significantly reduced stands in comparison to non-treated seed. Seven treatments were deliterious at Fort Collins, Colorado, and one treatment resulted in reduced stands at Longmont, Colorado.

## Discussion and Conclusions

Testing 14 seed treatments over a wide variety of soil and climatic conditions naturally involves a great many variables. Although temperatures and rainfall for the germination period were available for 10 of the tests they are not presented here since they can be in no way correlated with the results.

One of the surprising features of the experiments is the relatively poor performance of the New Improved Ceresan treatment. This treatment was beneficial in only two tests, while over a period of years it has proved a fairly reliable treatment for sugar beet seed. This cannot be explained as injury due to the chemical, since it only proved deliterious in the Jerome, Idaho, test, and laboratory germinations gave no indication of injury 6 weeks after treatment.

Perhaps one factor which contributed to the relatively poor performance due to treatments was the initial high germination of the seed. Laboratory tests indicated a germination of 90.0 percent and also that the seed was relatively free from molds. Contributing also to the lack of response from treatments was the fact that most cooperators reported very little to no visible post-emergence damping-off.

The paucity of positive results makes generalizing extremely hazardous. However, there seems to be a slight tendency for treatments which included 5 percent Arasan to give slightly better results over the area covered by the 9 tests which gave significant differences.

However, the results from these cooperative tests will have to be viewed in the light that they are only 1 year's results and that additional tests will have to be made before more definite conclusions can be drawn as to performance of individual or mixed fungicide treatments.

# The Damages Induced by a Severe Epidemic of Cercospora Leafspot on Susceptible and Resistant Varieties of Sugar Beets

DEWEY STEWART[1]

DURING THE SUMMER of 1947 a test was conducted on the Plant Industry Station to evaluate susceptible and resistant varieties of sugar beets under extreme conditions of leafspot exposure, with and without fungicidal treatment. The varieties U. S. 15, Line J, U. S. 215x216/2 and Improved U. S. 216 were included in the test. According to disease readings from tests conducted in sugar beet-growing regions over a period of several years the non-bolting variety U. S. 15 is leafspot susceptible, Line J and the 2nd release of U. S. 215x216 are resistant and Improved U. S. 216 is highly resistant. These varieties as well as others conform with reasonable constancy to previous classification as to disease reaction when grown in territories where climatic conditions restrict the growth of the pathogen *Cercospora beticola* or on the Plant Industry Station during the onset of the disease epidemic. However, after prolonged exposure to intense epidemics which occur most seasons on the Station it has been observed that varieties in the resistant categories do not perform as expected. Late in the season they show considerable blighting of the foliage due to an accumulation of spots on senescent leaves. Under comparable conditions the susceptible varieties react more violently to the disease and suffer a tremendous loss of foliage long before the leaves have served their useful span of life. Thus the susceptible and resistant varieties differ quantitatively, the resistant ones being characterized by smaller spots and fewer spots per unit of leaf area as well as a delay in the appearance of blight. It was the purpose of the test to appraise the extent to which varieties with this type of resistance are adequate to cope with a prolonged and unusually severe epidemic of the disease.

During the growth of the beets, methods were followed which favor the intensification of leafspot. The land had grown a crop of sugar beets the previous season and the infested tops were left on the ground. The climatic conditions which are usually hot and humid during late spring and summer were supplemented when needed by a sprinkler system. An occasional leafspot could be found in the seedling stands and this slight infestation was augmented by inoculation shortly after singling. Leaves of an overwintered crop of beets on which the pathogen was sporulating profusely were used as a source of inoculum. A suspension containing 5-10 spores per drop was applied on June 23 to each plant except those of the control plots. On July 25 the disease was considered to have reached epidemic proportions

[1]Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, Beltsville, Md.

when an abundance of leaf blight was observed in plots of U. S. 15. The disease condition worsened and soon all plants of the susceptible variety and the less tolerant phase of the resistant varieties were defoliated except for the few young leaves in the central buds.

With slight fluctuations in intensity, the disease epidemic continued until about October 10 when the growth of the pathogen was halted by a light frost and a period of cool nights. The period of disease exposure was approximately one half of the growing season from seedling emergence (April 28) to harvest, November 4. For a period of 75 days there was an appreciable loss of leaves due to blight. The disease injury was recorded using a scale of 0 to 10. On the scale 10 represented maximum injury and 1 designated severe spottings but essentially no blighting of the leaves. U. S. 15 received a score of 5.0 to 9.0 for the period of the epidemic while the highly resistant strain of U. S. 216 scored 0.5 to 3.0. The other varieties were intermediate in scores.

The Latin-square design with split plots was used for the test. The plots of the varieties were 8 rows wide and 20 feet long. The rows were 24 inches apart and the plants were spaced approximately 24 inches within the row. One half of each varietal plot received 8 applications of Bordeaux mixture at intervals of 8 to 10 days beginning July 11 to control the disease. The other half was exposed to the ravages of the disease. There were 2 Latin squares giving 8 plots of each of the 4 varieties which were divided into subplots for spray and no spray treatments. The results from the 2 squares have been combined into one summary as given in table 1.

In this test the differences between the sums of varietal performances are of minor concern whereas the comparison between spray treatments are of special interest. Each of the four varieties gave a highly significant gain for fungicidal treatment in acre yield of gross sugar and roots and in sucrose percentage. The spectacular difference for the susceptible variety U. S. 15 is thought to represent an extreme record of *cercospora* leafspot damage to sugar beets. If the differences between subplot means for acre yield of gross sugar as recorded in the table for each of the varieties are converted into percentages of the unsprayed half of the plot there are indicated gains of 127 percent, 126 percent, 122 percent, and 225 percent for Improved U. S. 216, U. S. 215x216/2, Line J, and U. S. 15, respectively. In like manner for acre yield of roots calculated gains of 87 percent, 68 percent, 79 percent, and 130 percent are obtained for the varieties in the order as given for gross sugar. The sucrose percentage was strikingly reduced for all varieties as a result of the disease. With the possible exception of the highly resistant Improved U. S. 216 which is a high-sucrose type, the quality of the roots from the unsprayed beets was below acceptable standards for factory use. In regions subject to less severe epidemics it should be possible to produce roots of acceptable quality if the most disease tolerant, high-sucrose varieties are planted. However, with the varieties available, such crops would be produced at a considerable sacrifice of acre yield of roots.

**Table 1.**—Summary[1] of 1947 field test conducted under conditions of severe leafspot disease exposure. Plant Industry Station, Beltsville, Maryland.

| Variety | Treatment[2] | Acre yield[3] | | Sucrose | Stand[4] |
|---|---|---|---|---|---|
| | | Gross sugar | Roots | | |
| | | (pounds | (tons) | (percent) | (percent) |
| Improved U.S. 216[5] | Spray | 3033 | 10.61 | 14.30 | 91.7 |
| | No Spray | 1337 | 5.68 | 11.83 | 83.3 |
| | Difference | 1696 | 4.93 | 2.47 | 8.4 |
| U.S. 215 x 216/2[5] | Spray | 3524 | 14.81 | 11.80 | 75.0 |
| | No Spray | 1561 | 8.80 | 8.90 | 65.7 |
| | Difference | 1963 | 6.01 | 2.90 | 9.3 |
| Line J[5] | Spray | 3407 | 13.31 | 12.83 | 62.0 |
| | No Spray | 1532 | 7.43 | 10.36 | 50.5 |
| | Difference | 1875 | 5.88 | 2.47 | 11.5 |
| U.S. 15[5] | Spray | 2744 | 13.22 | 10.56 | 66.2 |
| | No Spray | 845 | 5.74 | 7.24 | 42.1 |
| | Difference | 1899 | 7.48 | 3.32 | 24.1 |
| Significant difference between spray and no spray treatments for a variety | | | | | |
| | odds 19:1 | 467 | 1.44 | 0.80 | 9.3 |
| | odds 99:1 | 630 | 1.94 | 1.08 | 12.6 |

[1]Results given as averages of 8 subplots.
[2]One half of each plot of a variety received 8 applications of Bordeaux mixture.
[3]Calculated from average weight per root and a complete stand of 10,890 plants per acre.
[4]For the 3 rows harvested, a full stand would consist of 27 plants per plot.
[5]On a scale of 0 for no injury and 10 for maximum, the disease readings recorded for the no-spray treatment for period of the epidemic were as follows:

| | |
|---|---|
| Improved U.S. 216 | 0.5 to 3.0 |
| U.S. 215 x 216/2 | 2.0 to 5.0 |
| Line J | 1.0 to 4.0 |
| U.S. 15 | 5.0 to 9.0 |

In comparison of stands, attention is directed to differences between subplot means rather than to varietal differences. U. S. 15 suffered the greatest injury from the disease and also this variety gave the greatest difference in stand for treatments. Evidently, plants which have been defoliated by *cercospora* leafspot over a long period are more likely to be lost as a result of root rot.

## Summary

Leafspot resistant varieties have been introduced which afford essential control of the disease under epidemics as ordinarily experienced in regions where sugar beets are grown commercially. Nevertheless, representatives of resistant types showed a highly significant reduction in yield and quality under the extreme conditions of this test. These drastic exposures serve to indicate the need of further improvement in disease resistance before a feeling of security can prevail. Obviously varieties that would give crops completely free from *cercospora* leafspots would be more desirable than the tolerant types that have been introduced. However, such a goal seems to be far from attainable at the present time. The tendency for smaller spots and fewer spots per unit of leaf area associated with a delay in tissue breakdown will have to remain the basis for breeding for leafspot resistance until factors for immunity have been found and can possibly be incorporated into the genetical composition of the cultivated forms.

# Some Studies of Curly-top Virus in the Field

N. J. GIDDINGS[1]

IT HAS LONG been known that sugar beet leafhopper collections made in the winter breeding areas show a relatively small percentage of the insects carrying highly virulent virus. Collections made from sugar beet fields show that there is a rapid rate of increase in the percentage of viruliferous insects during the growing season and a far more rapid rate of increase in the percentage of those viruliferous insects which carry highly virulent strains of virus. The present paper deals with some of the factors involved in the explanation of each of these facts and includes data showing the effect of resistant sugar beet varieties on the amount of curly-top virus available to the sugar beet leafhopper.

The plants shown in figure 1 will help to clarify the question as to what is meant by "highly virulent" and "less virulent" strains of the virus. Susceptible sugar beet plants showing no greater injury than those in the two upper pots are considered to be infected by the less virulent strains while those showing injury comparable to the plants in the two lower pots are considered to be infected by the more virulent strains.

## Relative Prevalence of Highly Virulent and Less Virulent Strains of Curly-top Virus in Sugar Beet Fields and in Winter-breeding Areas

The data in table 1 give some evidence as to what happens in a commercial sugar beet field. These collections represent five different locations. The percentage of viruliferous leafhoppers in the first collection from each field shows a noteworthy degree of similarity and no insects carrying highly virulent virus were found in any of the collections previous to the one made April 27. It is, of course, reasonably certain that some insects carrying highly virulent virus were present in the fields when the earlier collections were made, but they were comparatively rare and there were none in the samples taken. There is a rapid increase in the percentage of viruliferous leafhoppers but an even more rapid rate of increase in the relative percentage of such insects carrying highly virulent virus. This greater rate of increase in the latter group may be partially accounted for by the fact that the total percentage of viruliferous insects reaches a "ceiling" but there are certainly other factors involved, and the percentage of leafhoppers carrying highly virulent virus also reaches a "ceiling" of 80 percent or 90 percent or higher in many fields by the close of the season.

The data in table 2 give some further evidence regarding seasonal and host relationships to virus content of the leafhoppers. The data represent the results secured from many leafhopper collections made from the central-

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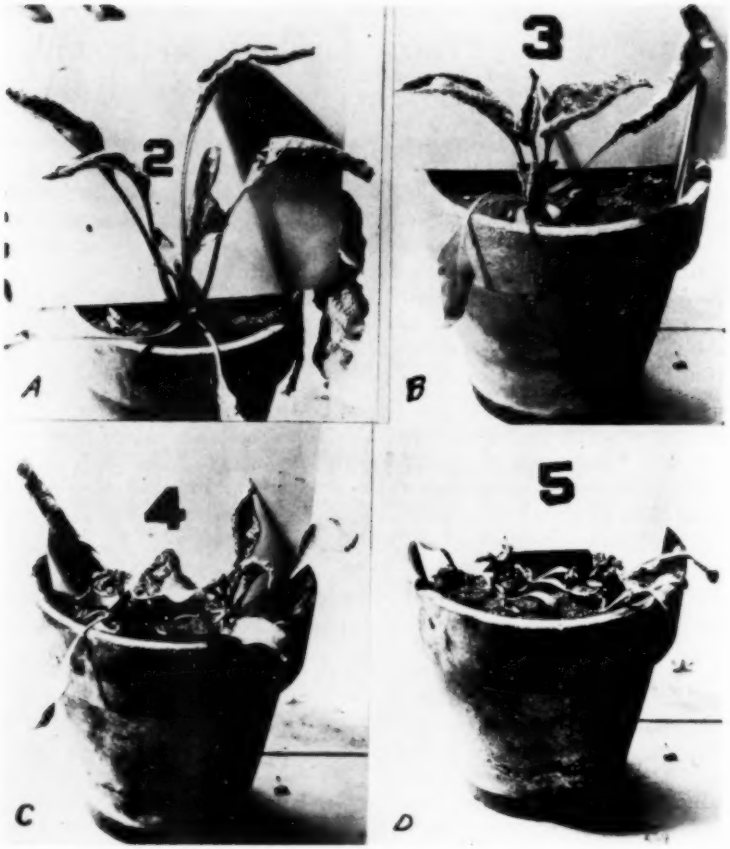


Figure 1.—Plants in the two pots at top show curly-top symptoms which are classed as due to the less virulent strains of virus, while those in the two pots at the bottom are classed as due to the highly virulent strains. The sugar beet variety is the susceptible S.L. 842.

western and northern-western portions of the San Joaquin Valley. Successive collections were made from the same general areas and are believed to be adequately comparable. The percentage viruliferous increased nearly four fold during the time after collections were made from the spring-breeding areas until the collections were made from the sugar beets in June and the percentage of these insects carrying highly virulent virus increased more than ten times during that same period. Our general experience would indicate that fields with so much of the highly virulent virus would show a much greater increase if collections had been made in July. The decreases shown by collections from fall and winter hosts may be accounted for by

the fact that a large portion of that population did not come from the beet fields but from highly resistant wild hosts such as Australian Saltbush, *Atriplex semibaccata* R. Br. The major fact brought out in table 2 is the ratio of leafhoppers carrying highly virulent virus to the total viruliferous on different hosts and at different seasons. The ratio is 1:7 (3 percent and 20 percent) for collections made from native annuals in the breeding areas during February and March, but drops to 1:2.5 for collections from sugar beets in June. The late fall and winter populations collected from wild hosts show a ratio of 1:5, while collections made from native annuals during the following April show a ratio of 1:16.5. The collections made in February must have consisted almost, if not entirely, of overwintering leafhoppers, while those collected in April probably contained relatively few of them.

**Table 1.**—Changes in virus content of leafhoppers in beet fields as season advances. Field tests from 1934 data.

| Location | Date | Leafhoppers | | | | |
|---|---|---|---|---|---|---|
| | | Total | Viruliferous | | Highly virulent | |
| | | (number) | (number) | (percent) | (number) | (percent) |
| Lane's Bridge, California | 4- 3 | 95 | 11 | 12 | 0 | 0 |
| | 4-18 | 39 | 6 | 15 | 0 | 0 |
| | 4-27 | 112 | 55 | 49 | 1 | 2 |
| | 6-17 | 118 | 93 | 79 | 10 | 11 |
| Madera, California | 4- 3 | 88 | 7 | 8 | 0 | 0 |
| | 5-14 | 238 | 90 | 38 | 1 | 1 |
| | 5-25 | 187 | 134 | 72 | 7 | 5 |
| | 6-17 | 118 | 80 | 68 | 8 | 10 |
| | 7- 2 | 111 | 78 | 71 | 19 | 22 |
| Dos Palos, California | 4- 3 | 88 | 8 | 9 | 0 | 0 |
| | 4-20 | 171 | 52 | 30 | 0 | 0 |
| | 5-14 | 171 | 76 | 44 | 1 | 1 |
| | 5-25 | 223 | 159 | 71 | 11 | 7 |
| | 6-17 | 208 | 156 | 75 | 14 | 9 |
| Atascadero, California | 4-11 | 145 | 18 | 12 | 0 | 0 |
| | 5-10 | 247 | 129 | 52 | 1 | 1 |
| | 5-22 | 232 | 187 | 81 | 33 | 18 |
| | 6-24 | 237 | 206 | 87 | 146 | 71 |
| Chowchilla, California | 4- 6 | 99 | 8 | 8 | 0 | 0 |
| | 5-14 | 81 | 65 | 80 | 0 | 0 |
| | 5-25 | 86 | 68 | 79 | 1 | 1 |
| | 7- 2 | 124 | 103 | 83 | 17 | 17 |

**Table 2.**—Some evidences of host and seasonal relationships of curly-top virus.

| Date | Source | Leafhopper collections | | | | |
|---|---|---|---|---|---|---|
| | | Total tested | Viruliferous | | Highly virulent | |
| | | (number) | (number) | (percent) | (number) | (percent) |
| 1934—February and March | Spring-breeding areas | 1512 | 306 | 20 | 10 | 3 |
| 1934—June | Sugar beets | 961 | 691 | 75 | 214 | 31 |
| 1934—October and November | Fall and Winter hosts | 2410 | 1099 | 45 | 83 | 8 |
| 1935—February | Spring-breeding areas | 916 | 366 | 40 | 29 | 8 |
| 1935—April | Spring-breeding areas | 1594 | 1045 | 66 | 39 | 4 |

Some of our winter annuals such as *Plantago erecta* Morris, *Lepidium nitidum* Nutt. and *Erodium circutarium* L'Her., when growing normally, are good hosts for the sugar beet leafhopper and excellent hosts for the curly-top virus. Since these winter annuals are very susceptible to all strains of curly-top virus it has seemed a bit surprising that the less virulent strains of virus are always so much more prevalent in the collections from the winter-breeding areas in the spring. Table 1 shows how the highly virulent virus increases rapidly in sugar beet fields, while table 2 and data from many other collections indicate relatively little increase of it in the annuals of the winter-breeding areas. There is even a reduction in some cases, as shown by the last three groups of collections in table 2.

Controlled inoculations of *P. erecta* and *L. nitidum* have revealed one factor which helps to explain the relatively low percentage of leafhoppers carrying highly virulent virus in field collections from these plants. Table 3 gives the data from a series of such inoculations.

**Table 3.**—Lethal effect of highly virulent curly-top virus on some California winter annuals.

| Host | Virulence of virus | Number tests made | Known infected plants | | | | |
|---|---|---|---|---|---|---|---|
| | | | Dead after approximately 40 days | | | | |
| | | | Totals | Totals | | Highest group | Lowest group |
| | | | (number) | (number) | (percent) | (percent) | (percent) |
| Lepidium nitidum | High | 4 | 493 | 373 | 76 | 93 | 53 |
| Lepidium nitidum | Low | 2 | 15 | 1 | 7 | 16 | 0 |
| Plantago eracta | High | 5 | 684 | 428 | 63 | 77 | 45 |
| Plantago erecta[1] | High | 1 | 180 | 81 | 45 | | |
| Plantago eracta | Low | 3 | 137 | 17 | 12 | 19 | 11 |

[1]The plants in this group were placed out-of-doors but were watered and cared for.

The figures given are for only those plants which were known to be infected. They either showed well-defined symptoms or were tested for the presence of virus and in many cases they were tested as well as showing symptoms. Among the plants inoculated with the less virulent strains of virus there were many which showed very slight symptoms, or none at all, but from which curly-top virus was recovered. Among those plants inoculated with the more virulent strains there were quite a few which died without showing any symptoms. Since the cause of death was uncertain, and there were some similar deaths among the other group, such plants were not included in these data. Plants infected by the highly virulent strains of virus were extremely dwarfed and distorted and made relatively little growth after symptoms became apparent. Such plants are unsatisfactory hosts for the sugar beet leafhopper. The amount of tissue available for feeding and egg laying is relatively small. Many eggs and young nymphs are destroyed and virus present in the plant is quickly lost as the host wilts and dies. One group of inoculated plants were placed out-of-doors since conditions in the greenhouse might be somewhat unfavorable to the host. This set of plants did show an appreciably lower percentage of dead plants but it should also be stated that we really tried to keep them alive and they

undoubtedly had far more favorable conditions for survival than would have been the case in the natural breeding areas. The roots of such plants are badly injured as a result of the infection and a few warm, dry days in the field result in early death, as has been observed in making late winter and early spring collections from the breeding areas. This means that the amount of highly virulent curly-top virus normally available from susceptible winter annuals is self-limiting and accounts, in large measure, for the fact that a very small percentage of the leafhoppers collected in those areas are carrying virulent virus. It is extremely fortunate that there is not a rapid increase of the highly virulent virus in the winter-breeding areas. A pronounced increase in such virus is very commonly evident in commercial sugar beet fields.

### Effect of Curly-top Resistant Sugar Beet Varieties Upon Increase of Virus

Another question involving the prevalence of curly-top virus is: What effect do resistant sugar beet varieties have upon the increase of the virus in commercial fields? The data bearing upon this question are somewhat limited but give a very clear answer.

Tests of leafhoppers from eight distinct locations where there were both susceptible and resistant sugar beets either in the same field or in nearby, comparable fields have shown approximately 10 percent *fewer* viruliferous leafhoppers obtained from the resistant beets than from the susceptible beets. The tests included 40 collections with a total of approximately 4,000 leafhoppers. The results are given in table 4.

The differences are not large but they are statistically significant. Figure 2 is a typical sample of the test plants inoculated by leafhoppers used in test 20 of table 4. The leafhoppers from a susceptible variety were obtained in the breeding plots conducted in cooperation with the Curly Top Resistance Breeding Committee north of Jerome, Idaho, and those from a resistant variety were collected from the Slagel field approximately 3 miles away. The fields were comparable except as to beet variety. Greater concentration of curly-top virus in the leafhoppers from the susceptible variety is evidenced by the higher percentage of viruliferous leafhoppers obtained (96 percent infection as compared to 86 percent infection from the resistant variety), and by the much shorter incubation period in the test plants.[2] The average incubation period in plants inoculated by leafhoppers from susceptible beets was 11.4 days, while in plants inoculated by leafhoppers from resistant beets it was 17.2 days. This 50 percent longer incubation period allowed the plants inoculated by leafhoppers from the resistant beet variety approximately 6 days more of normal growth than those inoculated by leafhoppers from the susceptible beet variety. That fact largely accounts for the apparently greater severity of symptoms (figure 2, right) in the test plants inoculated by leafhoppers from the susceptible beet variety.

[2]All tests made at that time showed relatively long incubation periods because of rather low temperatures.

**Table 4.**—Relative percentages of viruliferous leafhoppers among collections made from susceptible and from resistant sugar beets.

| Test No. | Location | Date | Leafhoppers from— | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Susceptible beets[1] | | | Resistant beets[2] | | |
| | | | Total | Virliferous | | Total | Viruliferous | |
| | | | (number) | (number) | (percent) | (number) | (number) | (percent) |
| 1 | Chino, California | 4-17-34 | 22 | 3 | 14 | 50 | 6 | 12 |
| 2 | Chino, California | 4-25-34 | 67 | 3 | 4 | 82 | 8 | 10 |
| 3 | Chino, California | 5-16-34 | 88 | 11 | 13 | 64 | 3 | 5 |
| 4 | Atascadero, California | 5-10-34 | 124 | 60 | 48 | 123 | 69 | 56 |
| 5 | Atascadero, California | 5-22-34 | 116 | 97 | 84 | 116 | 90 | 78 |
| 6 | Atascadero, California | 6-24-34 | 118 | 108 | 92 | 119 | 98 | 82 |
| 7 | San Ardo, California | 4-25-34 | 124 | 108 | 87 | 123 | 56 | 46 |
| 8 | San Ardo, California | 5-11-34 | 119 | 91 | 76 | 122 | 70 | 57 |
| 9 | Madera, California | 4-27-34 | 108 | 40 | 37 | 102 | 33 | 32 |
| 10 | Madera, California | 5-14-34 | 116 | 49 | 42 | 122 | 41 | 34 |
| 11 | Madera, California | 5-25-34 | 89 | 67 | 75 | 98 | 67 | 68 |
| 12 | Madera, California | 6-17-34 | 98 | 72 | 73 | 20 | 8 | 40 |
| 13 | Madera, California | 7 -2-34 | 44 | 37 | 84 | 67 | 48 | 72 |
| 14 | Dos Palos, California | 4-20-34 | 68 | 24 | 35 | 103 | 28 | 27 |
| 15 | Dos Palos, California | 5-14-34 | 75 | 37 | 49 | 96 | 39 | 41 |
| 16 | Dos Palos, California | 5-25-34 | 112 | 85 | 76 | 111 | 74 | 67 |
| 17 | Dos Palos, California | 6-17-34 | 92 | 65 | 71 | 116 | 91 | 78 |
| 18 | Bakersfield, California | 5-14-47 | 104 | 96 | 92 | 59 | 48 | 81 |
| 19 | Twin Falls, Idaho | 9-25-47 | 100 | 78 | 78 | 78 | 52 | 68 |
| 20 | Jerome, Idaho | 9-25-47 | 193 | 185 | 96 | 97 | 83 | 86 |

[1]The susceptible beet variety was Old Type except in test 18 where it was U.S. 15.
[2]The resistant beet was U.S. 1 except in tests 18, 19 and 20, where it was U.S. 22/2.

The symptoms on test plants indicated that the same virus strains were prevalent in approximately equal amounts in the collections from resistant beets and from susceptible beets. In other words, the difference in appearance of the two groups of test plants is not due to differences in curly-top virus strains. It is quantitative and not qualitative.

Figure 2.—The four pots at right show typical results secured on susceptible test plants used for the leafhopper collections from susceptible sugar beets in the breeding plots conducted in cooperation with the Curly Top Resistance Breeding Committee north of Jerome, Idaho. The four pots at left are typical of similar plants used for the leafhopper collection from the Slagel field of resistant beets north of Jerome, Idaho. Percentage infection was 96 and 86, respectively.

## Discussion and Summary

The general predominance of the less virulent curly-top virus strains in winter-breeding areas may be accounted for largely by the fact that the more virulent strains so quickly kill a high percentage of infected, winter, annual hosts. Many reservoirs of highly virulent virus are thus destroyed.

There is a rapid increase of virus in sugar beet fields because young beets are excellent hosts for both virus and vector. There is a great increase of the highly virulent virus in these fields because the plants infected with such virus live relatively much longer than infected winter annuals.

Leafhoppers collected from resistant sugar beets carry less curly-top virus than collections from nearby, comparable, susceptible beets. This is further proof (1) of the relatively low concentration of virus in the resistant beets. The data given in table 4 also indicates that many of us may have been overestimating the distances which leafhopper populations commonly move about after infesting sugar beet fields. It is thus suggested that reliable data on curly-top control by spraying may be obtained from well-separated portions of the same large field or possibly from nearby fields comparable as to beet variety, age of plants and cultural conditions.

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# Chemistry and Factory Operation

# Anthrone in Estimating Low Concentrations of Sucrose

E. E. Morse[1]

Although a number of methods have been developed for the estimation of low sucrose concentrations, the one which is universally used in sugar processing factories is the Molisch $\alpha$-napthol test. This is customarily used when the range of sugar concentration is 10-250 p.p.m., where it cannot be measured accurately by polarimetric means. Inasmuch as the $\alpha$-napthol test is a ring test, it cannot be adapted readily to transmittancy measurements and the sucrose content of a solution is usually reported after visual estimation to be a trace, light or heavy. Hand-colored cards have been used as standards, but they are far from being completely satisfactory.

The use of anthrone dissolved in concentrated sulfuric acid was suggested by Dreywood as the reagent in a qualitative test for carbohydrates (1).[2] The extreme sensitivity of this test plus the fact that it is not a ring test made it appear to offer a promising improvement over the $\alpha$-napthol test in the measurement of low concentrations of sucrose.

## The Chemical Anthrone

Anthrone is not easily available, at least in this country. The chemical used in this work was synthesized from anthraquinone, using the method in Organic Syntheses (2). Anthraquinone is reduced with tin and hydrochloric acid in a medium of glacial acetic acid, followed by recrystallization from benzene and petroleum ether. It can also be synthesized from O-benzoylbenzoic acid.

Whatever method of synthesis is used, it is important to use sintered glass filters to avoid the introduction of bits of filter paper which would cause a positive blank test.

Anthrone is the keto form of a tautomeric pair of which the enol form is anthranol. The equilibrium between the tautomers is represented by the equation in figure 1. The two substances have quite different properties. Thus anthrone is pale yellow in color, is insoluble in cold alkali and is non-fluorescent in dilute solution under ultra-violet light. It is comparatively unreactive, but will form addition compounds with Grignard reagents. Anthranol, on the other hand, is dark golden-yellow in color, is soluble in cold alkali, is highly reactive and fluoresces strongly in dilute solution under ultra-violet light. Anthranol is easily oxidized by bromine and, in fact, the proportion of anthranol in a mixture of the two tautomers can be determined by titrating with bromine in alcoholic solution under ultra-violet light until the fluorescence disappears (3).

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[2]The numbers in parentheses refer to literature cited.

In various solvents the proportion of anthrone to anthranol differs markedly. Thus in pyridine, tautomerization proceeds nearly completely to the enol form, while in glacial acetic acid, anthrone contains only 1.3 percent of the enol form at equilibrium (3).

Anthranol may be prepared from anthrone by dissolving the latter in alcoholic KOH, precipitating the anthranol with cold, dilute $H_2SO_4$, filtering and washing.

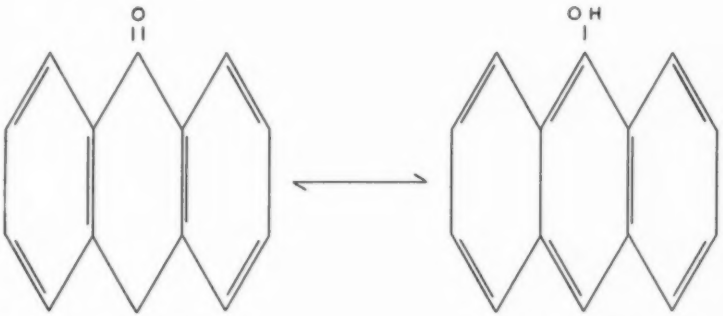


Figure 1.—Anthrone—anthranol tautomerization.

Inasmuch as the anthrone is used in concentrated sulfuric acid solution, it is of interest to know what tautomeric form exists in this solution. No information on this point was found in the literature, but for the following reasons it is believed that the keto form is the predominant substance:

1. 0.05 percent solutions of anthrone in concentrated sulfuric acid do not fluoresce under ultra-violet light. If anthranol solutions of the same concentration are prepared, they also do not fluoresce.

2. Both anthrone and anthranol solutions give practically indistinguishable color tests with dilute sugar solutions. This might indicate that anthranol tautomerizes immediately to anthrone in concentrated sulfuric acid, although it could indicate just the opposite change.

3. Freshly prepared solutions of anthrone in concentrated sulfuric acid give a negative test for enols with aqueous ferric chloride solution. However, as the anthrone solution stands, the bright canary-yellow color darkens to a pale orange and furthermore, a positive test for an enol is obtained. If the anthrone solution is stored at 0° C. in a refrigerator, very little color change is noted and a negative ferric chloride test is observed. This may be interpreted to mean that anthrone slowly tautomerizes to a small extent in sulfuric acid solution to form anthranol, a reaction which is slowed by reduced temperature.

### Reagent Strength and Keeping Property

Dreywood (1) recommended that the strength of the reagent be 0.2 percent. Preliminary experiments showed that the reagent strength could be reduced to 0.05 percent and still give tests of sufficient sensitivity to permit distinguishing between solutions containing 10 and 25 p.p.m. sucrose. The more dilute reagent offers an advantage because its bright yellow color is reduced. By using tubes of greater diameter, the strength of the reagent may be still further reduced. This offers no particular gain because an increased volume of reagent is required and furthermore, the larger test tubes are inconvenient to handle in making many routine measurements.

As previously stated, the anthrone used in this work was prepared according to the method in Organic Syntheses (2). Solutions of this material in concentrated sulfuric acid turned a brown-green color overnight. Since the presence of an impurity was suspected, the anthrone was recrystallized from glacial acetic acid to yield material which slowly changed to an orange-green color on long standing. A second recrystallization from the same solvent was of benefit, but not a third. Possible one recrystallization would be sufficient if an excess of solvent were used and the anthrone slowly crystallized and well washed with fresh solvent.

In order to test the keeping property of the anthrone reagent, various samples of anthrone in concentrated sulfuric acid were sealed in 18 mm. (outside diameter) Pyrex tubes and stored at room temperature. One sample was stored at 0 to 1° C. The transmittancies of the tubes relative to distilled water were measured at intervals. In figure 2 they are plotted relative to the initial transmittancy. These measurements were made in a Photovolt Lumetron colorimeter using unfiltered light.

The apparent anomaly that material which was recrystallized three times developed color faster than material which was recrystallized twice is believed to be due to the fact that the room temperature was higher during the test period on the former material.

Even solutions prepared from the purified anthrone and reagent grade sulfuric acid slowly darkened to an orange color on standing, due perhaps to anthranol formation. Other decomposition products are undoubtedly formed also. For that reason, it is suggested that the 0.05 percent reagent be freshly prepared every 3 or 4 days.

### Procedure

Because of the fact that temperature has a pronounced effect on the color forming reaction, it is important that the test be performed in a standardized manner. If the reagent is added to the sample slowly and the test tube is kept cool with cold water, a practically colorless solution can be obtained even though 2000 p.p.m. of sugar is present. Furthermore, if the tube is heated externally to boiling, the typical blue-green color is changed to a reddish-brown. By using the same volumes of reagent and sample solution, but varying the size of the test tube or other container

so as to vary its heat capacity, the upper temperature limit after mixing is altered and consequently the color. Precisely duplicable results in a test of this nature can only be secured by using a rigidly standardized procedure, adiabatically performed. The following procedure, however, will yield results which are quite consistent and suitable for the control laboratory:

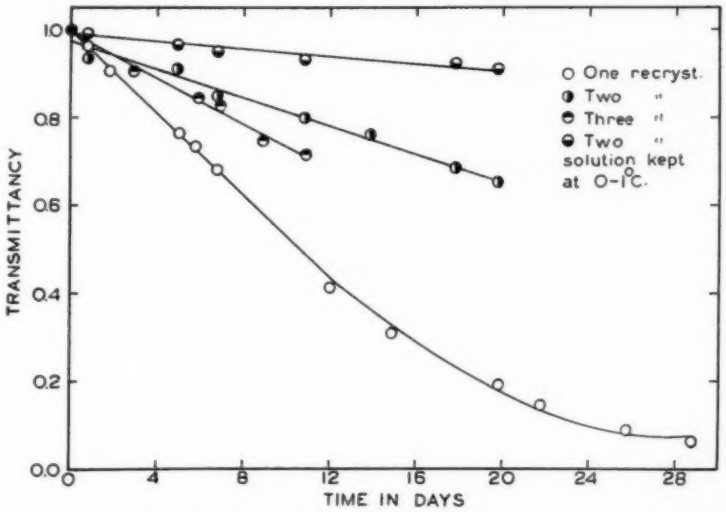


Figure 2.—Effect of recrystallization of anthrone on color development in 0.05 percent solutions.

2.0 ml. of the solution to be tested are measured into a clean, dry 15x125 mm. Pyrex test tube and 3.0 ml. of 0.05 percent anthrone dissolved in concentrated sulfuric acid (reagent grade) are added so as to form a bottom layer. The tube is then shaken to effect complete mixing. The transmission of the solution for white light is next measured in a photoelectric colorimeter. Distilled water is used as the standard, with its transmission taken to be 1.000. By reference to a previously prepared calibration curve or table, the concentration of sucrose in the original sample is ascertained. Table 1 and figure 3 present calibration data obtained with a Lumetron photoelectric colorimeter, Model 402E, manufactured by the Photovolt Corporation, New York, N. Y.

**Table 1.—Light tranmission of sucrose solution-anthrone mixtures.**

| | | |
|---|---|---|
| Distilled water | 1.000[1] | 1.000[2] |
| Anthrone reagent + distilled water | 0.791 | 0.783 |
| Anthrone reagent + 10 p.p.m. sucrose solution | 0.659 | 0.658 |
| Anthrone reagent + 25 p.p.m. sucrose solution | 0.493 | 0.498 |
| Anthrone reagent + 50 p.p.m. sucrose solution | 0.317 | 0.323 |
| Anthrone reagent + 125 p.p.m. sucrose solution | 0.115 | 0.109 |
| Anthrone reagent + 250 p.p.m. sucrose solution | 0.024 | 0.024 |

[1]Anthrone reagent prepared 4 hours previously.
[2]Anthrone reagent prepared 27 hours previously.

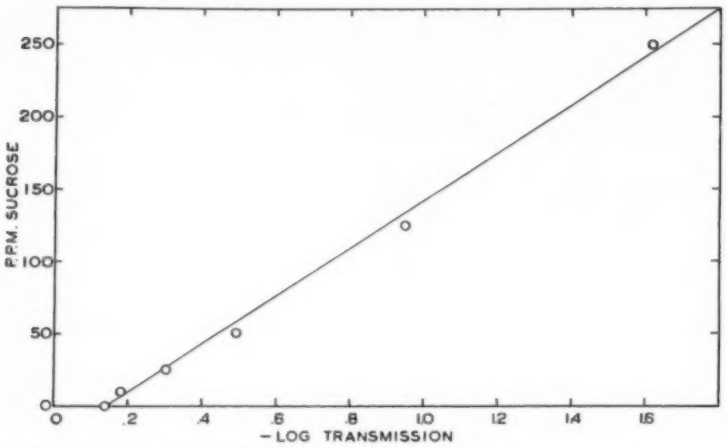


Figure 3.—Light transmission of sucrose solution—anthrone mixtures.

## Rate of Color Development

**Determinations were made of the time required to reach the maximum color density after mixing the reagent and solutions containing various concentrations of sucrose. In these determinations, the sucrose solution was contained in one test tube and the reagent in another. At zero time the solutions were mixed by pouring the reagent into the sucrose solution and then pouring the mixture back into the first tube. Transmittancy readings were taken at frequent intervals until the reactions were substantially complete. In figure 4 the optical density (-log transmittancy) is plotted against time after mixing. The transmittancies are the values relative to the transmittancy of the blank.**

**Table 2 shows the time required to reach 90 and 95 percent of the final density. A delay of 2 minutes before measuring the color will insure that 95 percent of the color has been developed, while about 90 percent is developed in 1 minute.**

## Method of Color Measurement

The photoelectric colorimeter provides the most accurate and convenient method of color measurement. Various types of instruments can be used, depending on the degree of precision required. For the average factory laboratory, a single photocell colorimeter in which the transmittancy is indicated by the deflection of a microammeter is probably suitable. This may be calibrated using the particular test tubes (usually 15-18 mm.) which fit the holder. The data presented in table 1 were taken from two runs

made on successive days with sucrose solutions which were freshly prepared just before the tests were conducted. It is difficult to evaluate the precision of the method with only two runs, but the difference between these runs amounts to about 2 percent, based on the sucrose content.

If it is desired to use a visual comparison method, Lovibond standard color plates may be used in a suitable constructed comparator. It is possible to make close matches between the plates and the coloring matter produced in the anthrone test. This method offers an advantage if the samples are turbid because one can disregard the turbidity to a large extent in matching colors.

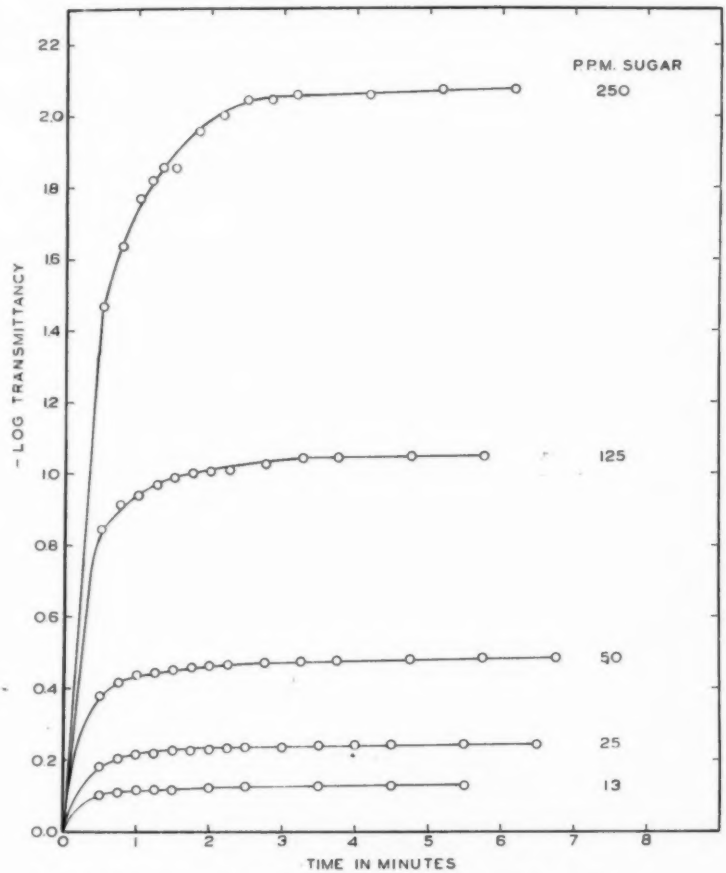


Figure 4.—Rate of color development in solutions of anthrone reagent and sugar.

Table 2.—Rate of color development in anthrone test.

| P.P.M. Sucrose | Maximum Density | Time to reach 0.95 maximum density (minimum) | Time to reach 0.90 maximum density (minimum) |
|---|---|---|---|
| 250 | 2.07 | 1.8 | 1.4 |
| 125 | 1.05 | 1.5 | 1.0 |
| 50 | 0.49 | 2.1 | 1.1 |
| 25 | 0.24 | 1.8 | 1.1 |
| 12.5 | 0.13 | 1.8 | 1.1 |

Primary standards made up from the anthrone reagent and sucrose solutions of known concentration and sealed in Pyrex tubes were not found to be satisfactory because the blue color gradually fades and the solution becomes slightly cloudy. At the higher sugar concentrations, a slight amount of dark-colored material coats the inside of the tubes.

Other color standards which might be used include color transparency film such as Ekatchrome, hand-colored cards or Carbro prints. These have not been found to be satisfactory, inasmuch as the colors in the film are not permanent and the latter two means make use of reflected rather than transmitted light.

## Effect of Impurities

**The impurities commonly present in the condensed water samples of a beet sugar factory do not interfere seriously in this test. Solutions of diffusion juice, thick juice, molasses and Steffen filtrate were prepared, each containing 200 p.p.m. of sucrose. The blue-green colors formed in the first three solutions were closely the same, but an olive-green color was obtained with the Steffen filtrate sample. This is not surprising when the low sugar to solids ratio of this material is considered. A special calibration would be required for the accurate measurement of the sucrose content of condensed waters containing Steffen filtrate.**

## Comparison With Alpha-Naphthol Test

The main advantage of anthrone is that it gives a more accurate and more sensitive test than $\alpha$-naphthol. The coloring matter is distributed throughout the whole body of the solution and is not concentrated in a shallow ring. Furthermore, the extent of agitation of the tube has no effect on the test as it does with $\alpha$-naphthol. Solutions containing 10 and 25 p.p.m. can be readily distinguished from each other. It is very difficult with the $\alpha$-naphthol test to make this distinction.

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# An Automatic Polariscope

W. O. Bernhardt[1]

One of the sugar technologists' most important tools is the polariscope. It permits rapid and reliable determinations of the sugar content of juices during the many stages of manufacture. Most polariscopes now in use permit readings to one tenth of a degree and estimation of five one hundredths of a degree of sugar. When a high degree of accuracy is required, as many as ten readings are generally made and averaged. Such procedure is entirely satisfactory when time is not a limiting factor.

In tare laboratories the polariscope is employed for the determination of the sugar content of beets as they are received from the grower. Because of the large number of samples involved it is not possible to make more than one reading and the accuracy depends upon the skill of the tare chemist. Since the operator must generally make about two hundred readings per hour it is customary to have two such operators, working alternately in half-hour shifts. Fatigue of the operators makes itself felt in a number of ways. The eye may become tired and may no longer be able to determine accurately when the halves of the polariscope field are in balance. Fatigue of the mind results in erroneous reading of the vernier scale and lastly errors occur in the transfer of the readings to the tare ticket. All this points to the human element as the major source of error, and its elimination appears highly desirable. This fact has been recognized for many years, and ever since photoelectric cells were available attempts have been made to substitute such cells for the human eye in the balancing of polariscopes.

## Historical Development

Stanek and Sandera (5)[2] of Prague disclosed in 1925 that they had worked on such a scheme for more than 20 years. Instead of using the now customary half-shadow method they attempted to determine photoelectrically the point of extinction, i.e. that point at which the plane-polarized light emanating from the sample tube vibrates at right angles to the plane of polarization of the analyzer. In 1926 they employed a single selenium cell and vacuum tube amplifier, but the degree of accuracy was only on the order of one degree sugar. It was reported that each reading took nearly 10 minutes.

Miss Winifred E. Dickes of London (2), working also on the point of extinction, reported the design of an apparatus involving the use of a slit and a selenium cell. Accuracy was reported to be on the order of 0.01 degree sugar but a number of readings had to be taken roughly 90 degrees apart and averaged. In 1924 Miss Dickes was considering the

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[2]The numbers in parentheses refer to literature cited.

addition of vacuum tube amplification and the design of a self-balancing, recording polariscope.

Halban and Seidentopf (1) of Germany worked on a similar arrangement and were granted a patent in 1922. They claimed a precision of 0.01 degree with light in the ultra violet region.

Strelkow (6) of Russia employed a half-shadow device in 1926 and used two selenium cells in a bridge circuit with a sensitive galvanometer. He utilized the heat of the light source and two thermocouples to produce the potential for the selenium cells. No data on accuracy were published.

Singh and Rao (3) of the Benares Hindu University also worked with a half-shadow device in 1937. They used not only two selenium cells but also two polariscopes and sample tubes in parallel. One tube contained the sugar sample solution and the other distilled water. The selenium cells were first balanced without the tubes in place. The tubes were then placed in the polariscopes and balance established through adjustment of the polariscope containing the sample. The tubes were then exchanged and balance re-established by adjustment of the other polariscope. The mean of the two readings then indicated the polarization of the sample.

Spengler and Hirschmueller (4) of Germany worked on a half-shadow device in 1940. They used Polaroid foil in the polarizer and analyzer. Two photoelectric cells of the barrier layer type were used in a bridge circuit. With the sample in place the analyzer was removed and the cells balanced. The analyzer was then replaced and the cells again balanced by rotation of the analyzer. The degree of rotation was read on a vernier scale. The accuracy was claimed to be on the order of 0.1 degree sugar. The firm of Lange in Germany undertook the manufacture of this instrument but the first model submitted for tests to the Berlin Sugar Institute had some mechanical defects. Due to the war nothing further was heard about this development

Undoubtedly many unnamed investigators have worked on this problem.

Early in 1941, R. A. McGinnis and E. E. Morse of the Spreckels Sugar Company experimented with the idea of reading the polariscope by photoelectric means. During 1944, J. R. Earl, a physicist employed by the Spreckels Sugar Company, advanced an idea involving the use of magneto-optical cells, operating on the so-called Allison magneto-optic effect. Later the use of a mechanical light chopper was suggested. Many tests were made and a preliminary report of January 1945 indicated that the system was workable. The work was interrupted due to the scarcity of materials during the war years. Late in 1946, Mr. Earl resumed this project but left the Company in April 1947 without completing the work. It was believed at that time that the remaining problems could be solved in the near future and the project was brought to completion by the author. The photoelectric circuit and the self-balancing mechanism were soon completed and the first model was demonstrated in July 1947. This model, which adjusted itself to balance without any manipulation by the operator, still required the reading of the vernier scale by eye. The development of a printing mechanism, coupled to the vernier scale, had been undertaken by us some time

ago and it was now modified to operate with the self-balancing polariscope. The first model of the now fully automatic polariscope was rushed to completion in time for the latter part of the 1947 campaign. It was in continuous use in the Woodland tare laboratory from October until the end of the campaign. A total of 34,838 tare samples were run through the machine. The standard deviation for the instrument is surprisingly low. The following table will illustrate this point (table 1). The test samples upon which this table is based were interspersed with regular tare samples and, therefore, also include any deviation which may be caused by improper scavenging of the continuous tube. A summation of the table indicates a mean standard deviation for the machine of 0.04 against 0.18 for a skilled operator on a manually operated polariscope.

**Table 1.**

| | Series 1 | Series 2 | Series 3 |
|---|---|---|---|
| **High Color Solutions** | | | |
| Tare chemist, average | 17.95 | 16.07 | 16.89 |
| Tare chemist, $\sigma \pm$ | .103 | .508 | .109 |
| Automatic Polariscope, average | 17.89 | 16.04 | 16.92 |
| Automatic Polariscope, $\sigma \pm$ | .046 | .049 | .027 |
| **High Turbidity Solutions** | | | |
| Tare chemist, average | 16.58 | 16.33 | 14.98 |
| Tare chemist, $\sigma \pm$ | .096 | .218 | .129 |
| Automatic Polariscope, average | 16.48 | 16.57 | 14.97 |
| Automatic Polariscope, $\sigma \pm$ | .078 | .013 | .040 |
| **Clear Solutions** | | | |
| Tare chemist, average | 15.52 | | |
| Tare chemist, $\sigma \pm$ | .117 | | |
| Automatic Polariscope, average | 15.48 | | |
| Automatic Polariscope, $\sigma \pm$ | .035 | | |

## Description of Polariscope

The automatic polariscope (figure 1) employs a Bausch and Lomb saccharimeter equipped with a Lippich type double-field polarizer. Fully automatic operation, i.e. automatic balancing of the saccharimeter and printing of the sugar content of the sample onto the tare ticket is achieved by a modulated beam of light which is converted into electrical impulses. These impulses cause operation of a motor in such a manner that the compensating wedge in the saccharimeter moves towards the point of balance. The printing mechanism is coupled to the compensating wedge so that for any point of balance between 0 and 30 percent sugar a result corresponding to the reading on the vernier scale of the saccharimeter is printed onto the ticket.

In the Lippich double-field polarizer the incident light receives a different treatment in the two halves of the field insofar as the plane of polarization in one half of the field differs from that of the other half by a small angle, generally called the half-shadow angle. When the analyzer is so oriented that its plane of polarization essentially bisects the half-shadow angle, the halves of the field transmit the same amount of light and the field appears evenly illuminated. When a substance of rotatory power is placed between the polarizer and analyser the halves of the field no longer appear equally bright. A movement of the quartz compensator wedge in the proper

direction then again restores the field to balance. In the automatic polariscope a revolving semi-circular shutter scans the field continuously at a rate of 3,600 revolutions per minute. Thus, in the case of an unbalanced field, the intensity of the light reaching the phototube varies between a minimum and a maximum (see figure 2). The current passed by the anode of the phototube varies with the intensity of the light and since this occurs 3,600 times per minute the phototube and amplifier produces a 60-cycle alternating current. The rotating shutter is so positioned that the resultant A. C. is always 90 degrees or 270 degrees out of phase with the main line A. C., depending on which side of the field is darker. The combination of main line A. C. and that produced by the amplifier causes the balancing motor to operate. The rotation is either clockwise or counterclockwise, depending on the direction of unbalance. The mechanical connections are so arranged that

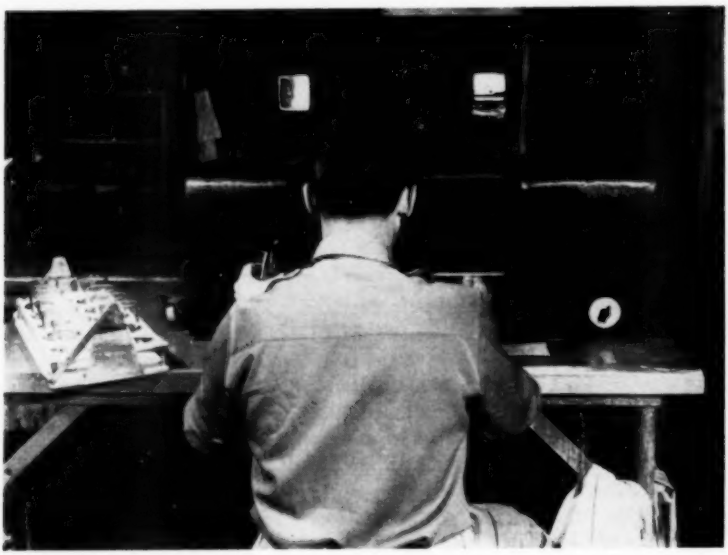

Figure 1.—Automatic polariscope in use.

the quartz compensator is always driven toward the point of balance. When the balance point is reached no more alternating current reaches the balancing motor from the amplifier and it no longer moves the compensator. The printer is coupled to the compensator so that at the balance point the percentage of sugar is directly printed onto the tare ticket. In tare laboratory practice the sample is generally read to the nearest one-tenth of one percent. The automatic polariscope permits estimation of one-hundredth of one percent.

Figure 1 shows the operator seated before the instrument. His left hand holds the beaker containing the sample. A slight upward pressure with the beaker against the inlet tube causes the automatic siphon valve to take the sample into the machine, removal of the beaker automatically closes the valve. The tare ticket is in the printer holder. Pushing the holder into the machine causes the printing mechanism to function, and the completed ticket is withdrawn. In the present form polarizations may be read and printed at the rate of 1 every 9 seconds or 400 per hour.

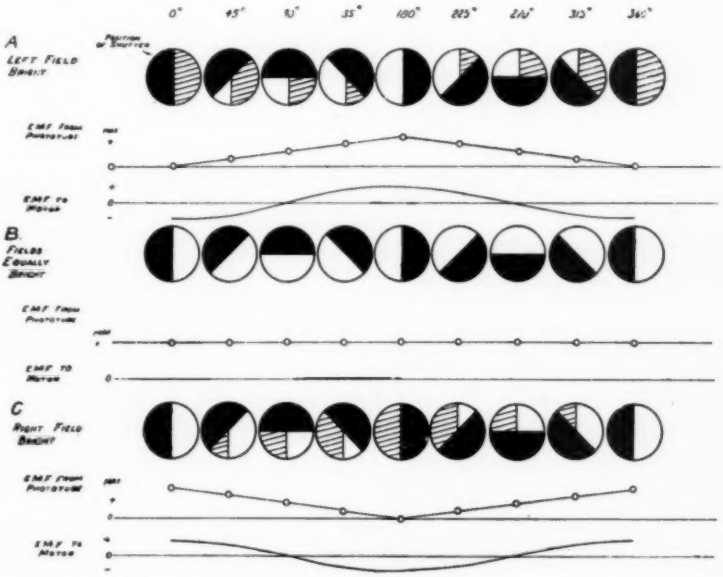


Figure 2.—Principle of phase reversal.

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# Kinetics of Sucrose Crystallization
# VII. Real Massecuites[1]

WILLIAM P. WHELAN, JR.,[3,4] THEODORE T. GALKOWSKI,[3,5] AND ANDREW VAN HOOK[6]

A QUANTITATIVE specification of the melassigenic nature of sugar syrups is a matter of considerable interest and value to the sugar boiler. The older concept, which is based upon solubility behavior alone (6)[2], is obviously incomplete for it ignores the very significant factor of the finite and often limiting rate of crystallization which is encountered in practice. Although many workers have studied the rates of crystallization of sucrose from pure and natural syrups (reviewed in 5), they have, in general, omitted an exact, quantitative definition of the melassigenic property. A semi-empirical method has recently (5-f) been devised for assigning such a definite, numerical value to this factor for any given syrup. The objects of the present paper are:

1) to continue the study of the application of this method to natural syrups of different types,
2) to confirm, or not, the general behavior observed in previous experimental studies, and
3) by such evaluation of the melassigenic behavior as is possible, to provide the beginnings of a classification of syrups according to their crystallization rate inhibiting powers.

The melassigenic factor, therefore, is employed in this work with the specific implication of the rate inhibiting effect of the non-sucrose substances, or impurities, present. This kinetic interpretation includes the solubility factor as contained in the basic rate equation:

$$\text{Velocity} = k\,(a - a_{sat.})$$

The substitution of concentrations as molalities, or their equivalent, for activities, a, has been found to be satisfactory as a first approximation (5). It has also been observed that the specific reaction rate constant, k, is a simple semi-logarithmic function of the impurities present (5); and it is this behavior which forms the basis for the melassigenic rating suggested. Earlier workers, while recognizing that "the quantity and character of the non-sugars present in the syrups are, in the last analysis, the predominating factors in determining the rate at which sucrose will crystallize from them (4)", have been unsuccessful in providing data which lead to a ready evaluation of these factors.

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[1]Six previous papers in this series have been published (5)$_{a-f}$; of which 5-f bears the same subtitle as the present one.
[2]The numbers in parentheses refer to literature cited.
[3]Submitted in partial fulfillment of the requirements for the M.S. degree at the College of the Holy Cross.
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[5]Present address: Department of Chemistry, Ohio State University, Columbus, Ohio.
[6]Department of Chemistry, College of the Holy Cross, Worcester, Mass.

The method of evaluation proposed in the present work may, besides yielding data which may have direct application to control practices in industry, provide information of value in the eventual determination of those impurities having the greatest crystallization inhibiting effect on sucrose. The elimination of these substances from syrups, or from cane and beet themselves, is conceivable (1). The definition also fulfills the condition prescribed by Hungerford (2) in being "A quantitative estimate of crystallizability—independent of operating conditions—measures crystallizability as a property of the syrup itself."

**Table 1.**—Source and composition of stock molasses.

| Molasses | Source | Dry substance | True purity | Raffinose on D.S. |
|---|---|---|---|---|
| 1. Refiner's Blackstrap | Revere Sugar Refinery | 73.0% | 41.92% | -- |
| 2. Puerto Rican Syrup | Unknown | 74.2 | 62.5 | -- |
| 3. Non-Steffen No. 1 | Alma, Mich., 1946/47 Michigan Sugar Co. | 83.5 | 63.45 | 0.0% |
| 4. Non-Steffen No. 2 | Clarksburg, Calif., 1946/47 Amer. Crystal Sugar Co. | 83.4 | 64.1 | -- |
| 5. Louisiana Blackstrap | New Iberia, La., 1946/47 Iberia Sugar Coop., Inc. | 83.3 | 30.3 | -- |
| 6. Steffen No. 1 | Mason City, Ia., 1946/47 Amer. Crystal Sugar Co. | 83.8 | 66.0 | 2.9 |
| 7. Non-Steffen No. 3 | Chaska, Minn., 1946/47 Amer. Crystal Sugar Co. | 83.2 | 63.1 | 1.6 |

## Experimental

Massecuites were made up to 8 molal with respect to sucrose from the several cane and beet molasses described in table 1. This concentration happens to be a most convenient one for many natural syrups; but any other definite concentration yields the same results (5)—provided, of course, that it is supersaturated to a reasonable degree. The values given in the table are true dry substance and sucrose by double polarization; although refractive index solids, and single polarization sugar (in the case of beet products), give approximately the same, final melassigenic quotient. The rates of adjustment at 30 degrees C. were followed refractometrically after inoculating with a fixed amount of seed (6X Confectioner's to crystallizable sucrose=0.47). The saturation refractivities were taken after 24 hours; but it has been observed with many syrups that use of the 2-hour value does not alter the rate curves appreciably, unless the rate is extremely slow. In this case a higher sucrose concentration is advisable to accelerate the observations. A plot of the negative logarithm of the fractional refractive index change against the time is a straight line over most of the life of the run, and the slope of this curve is the specific reaction rate constant, k, in the integrated rate equation:

$$\ln \frac{n_o - n_{sat.}}{n - n_{sat.}} = kt$$

The velocity constant is expressed most conveniently relative to that of a pure sucrose solution of the same molality. Absolute values of the growth

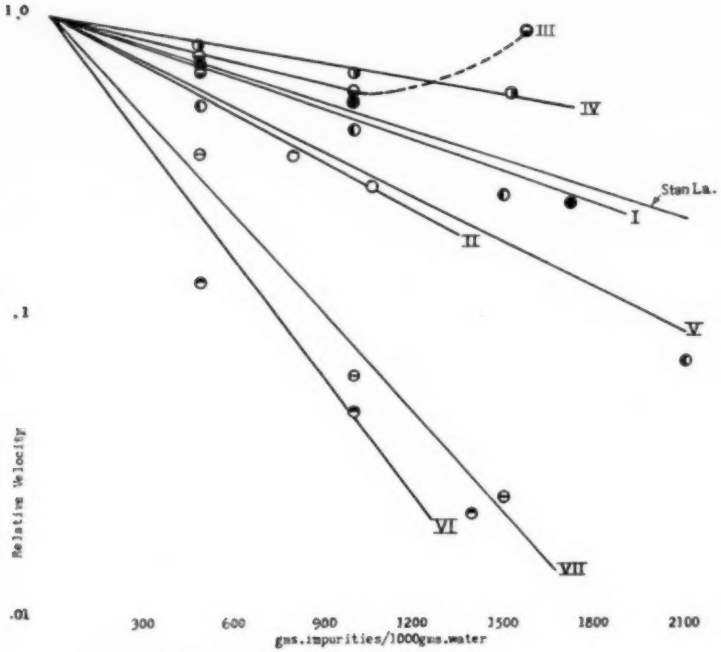


Figure 1. Melassigenic Curves

● - Sample I - Refiner's Blackstrap
○ - " II - Puerto Rican Syrup
◒ - " III - Non-Steffens #1
◑ - " IV - Non-Steffens #2
◐ - " V - Louisiana Blackstrap
◓ - " VI - Steffens #1
⊖ - " VII - Non-Steffens #3

rate may readily be estimated from the previously determined value of 100 g/m²/hr. for pure sucrose at 8 molal. This value is almost exactly the same as Kucharenko's value (3).

## Results and Discussion

For solutions of the same sucrose molality, identical crystallizing surface, etc., the activity theory of crystallization rate suggests:

$$\log(\text{Rel. Velocity}) = iI$$

The slope of the relative velocity versus the Impurity, I, (as g./1000 g. water) curve on semi-logarithmic coordinates, thus defines the coefficient i,

which may be considered to be the melassigenic factor. Most of the syrups which have been examined to date confirm this equation in at least an approximate way. As a minimum, only one velocity determination is required, although at least three are utilized in each of the results represented in figure 1. With the exception of Syrup III, these curves fall into the general pattern demanded by the above expression. If the melassigenic rating suggested in an earlier paper (5-f) is extended to include these present data, the following table 2 is obtained.

**Table 2.**—Relative melassigenic nature of syrups arbitrary i values.

| Syrup | i |
|---|---|
| 4. Non-Steffen | 0.6 |
| 3. Non-Steffen | 0.8 |
| Standard Cane[5] | 1.0 |
| (Pure invert sugar | 1.05) |
| 1. Refiners' blackstrap | 1.1 |
| 5. Louisiana blackstrap | 1.7 |
| Steffen No. 2[5] | 1.8 |
| 2. Puerto Rican syrup | 1.9 |
| Cane[5] | 2.0 |
| Non-Steffen No. 1[5] | 2.1 |
| Louisiana Cane[5] | 2.2 |
| 7. Non-Steffen | 3.7 |
| Steffen No. 1[5] | 4.1 |
| Non-Steffen No. 2[5] | 4.6 |
| 6. Steffen | 4.7 |

[5]This number refers to the designation employed in reference (5-f).

No particular classification is observed; but the range in values suggests that the melassigenic factor, *i*, may have some significance in representing the boiling and crystallizing behavior of massecuites. The abbreviated methods of the present paper also suggest the possibility of practical utility.

## Acknowledgment

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# Sugar End Operation on Ion Exchange Juice

H. E. Ellison[1]

THE OPERATION of a beet sugar factory consists of two separate and distinct processes: the beet-end operation and the sugar-end operation.

The beet-end operation consists essentially of three major steps; first, the extraction of the sugar-containing juice from the beet; second, the chemical elimination of a certain proportion of the impurities from this juice; and finally its concentration in multiple effect evaporators. The sugar-end operation is devoted almost entirely to the crystallization and separation of the practically pure sugar crystals from the thick juice obtained from the beet-end. However, purification may be said to take place on the sugar-end also because the remaining impurities are successively concentrated in the mother liquors by the various boilings until they eventually end up in the final molasses.

In the history of beet sugar refining, there has been used a wide variety of methods for removing impurities from the raw juice. The standard and most successful of the various methods has been lime defecation which is capable, when properly done, of removing approximately 45 percent of these impurities. Sulphitation is also almost universally used for impurity and color removal.

Ion exchange gives sugar technologists a new tool to more effectively remove impurities from sugar solutions. Through the use of this new tool, we are able to eliminate about 90 percent of the total impurities, giving us a more pure sugar solution than we have ever before obtained. Many of the worst salts not removed by old methods are removed by ion exchange, so that what is left is, practically speaking, an ash-free and sulphur-free sugar. In ion exchange juices there are none of the disagreeable tastes or odors that are present in regular beet operation.

Table 1 shows average values on some of the pertinent data on the influent (filtered second carb juice) and effluent juice from the exchangers.

**Table 1.**

| | Influent | Effluent |
|---|---|---|
| Brix | 12.95 | 11.81 |
| Percentage sugar | 12.13 | 11.61 |
| Purity | 93.76 | 98.60 |
| pH | 8.14 | 7.13 |
| Invert | .13 | .36 |

Our present sugar-end equipment is inadequate to obtain the ultimate extraction of sugar from the type juice put out by ion exchange. We have on the bottom floor of the factory, six machine syrup tanks, each with a

[1]Superintendent, Layton Sugar Company.

capacity of 302 cubic feet. In addition, we have seven tanks on the pan floor. These, with their capacities and the manner in which they were used are shown in table 2.

**Table 2.**

| Tank No. | Capacity | Syrup |
|---|---|---|
| | cubic feet | |
| 1 | 502 | Standard syrup |
| 2 | 502 | Standard syrup |
| 3 | 502 | High green |
| 4 | 502 | 2nd boil green |
| 5 | 251 | Machine syrup |
| 6 | 251 | 3rd boil green |
| 7 | 283 | Molasses |

We started on a four-boil system, but found we had to add too much low purity syrup back with the high purities to get a final molasses of sufficiently low purity. We then put a charge line from the molasses tank into the low raw pan and were able to figure out a five-boil system. This still was not a desirable method because considerable inboiling of low purity syrups was yet necessary to bring the final molasses to the requisite low purity. The boiling of the high purity thick juices from the ion exchange process is very much the same as the similar working of thick juices from the conventional refining process. However, on the lower purity syrups this is not true. Here we found that we needed a very much better circulation in the pan than heretofore. In all cases, it was impossible to brix the pans as heavy as with regular beet juices.

At Layton we have three pans. The white and intermediate are coil pans, and the low raw is a calandria. In the regular white pan we boiled only the standard thick juice or the first boil pan. In the intermediate pan we boiled all second-boil sugar, which was made up of a mixed graining charge of high green and standard thick juice and finished on straight high green. This massecuite was dropped to the white mixer, spun out, dried, and sacked as white sugar. The intermediate pan was also used for third and fourth boil, which consisted of melted sugar coming back to the white side. The syrup from this third and fourth boil was taken to the low pan for a crystallizer boil. The crystallizer sugar was returned to the beet-end and the syrup discarded. We averaged a discard in about every 18 pans.

We found that we needed better pan circulation, especially on the low purity side of the sugar-end more particularly in the low raw pan. It was impossible to boil a low pan and hold it more than 4½ to 5 hours. This was due to the fact that the impurities giving high viscosities are removed by ion exchange; so that when the crystals reach a certain size, they settled out like sand. Before we learned this fact, we dug and melted out a few low raw pans of sugar. On the basis of the five-boiling system, indications are that a total of 93.5 percent extraction is feasible, with a probable

true purity of 57.5 to 58.5 in final molasses. The campaign average at Layton, including 18 days of straight house operation, was 58.59 purity on molasses. For the ion exchange period we had 57.41 average.

Our thinking on possible changes to make a good balance on the sugar end for this new juice would be to: 1.—materially increase holding tanks so that we have enough tankage to handle syrups for a seven-boiling system, 2.—to improve and increase pan circulation, especially on the low raw pan so that all of our melt sugar could be boiled in this pan, 3.—to obtain three new centrifugals for white first and second boil and to move two of our present automatic machines to third and fourth boil service and the other two automatic machines to high raw service, and 4.—to so split our sugar mixers that we will have four instead of three mixers and to so arrange the sugar scroll that we can blend third and fourth boil sugar with first and second.

It is evident from our experiences this year that we can get four white strikes of sugar by using standard syrup with the various greens for graining charges. In doing this, however, it will be necessary to add a decolorizer such as activated carbon to the syrup from the second boiling and then to give it a careful filtration with filteraid before third boiling.

In order to more fully utilize the three pans we have, it seems that the feasible thing is to boil all the low and melt sugar in the calandria pan. In order to do this, we will have to add a heating coil under the calandria and one above to induce greater natural circulation and also to take advantage of vapor heat.

To get a better and more uniform sugar throughout, we think it important to have controlled cycles on all centrifugals except the low raw; so we think in terms of three new machines on first and second sugar with automatic wash and syrup separation, two of our old machines with automatics and heavier wash on third and fourth, and two automatics on so-called high raw.

We plan to have two white mixers in line so the two pans can work together, rather than separately. In having mixers, centrifugals, and scrolls in a straight line, it will be possible to more completely blend the sugars by a part blend in the scroll and finish in the sugar dryer without a lot of extra blending equipment.

The purity control we think we will try for, is a straight purity drop all the way through. In attempting to get four white strikes of sugar we are sure that the wash and green will have to progress together. In other words, we do not think it necessary to separate the green from the wash on any but fourth boil. For obvious reasons we figure on an extremely clean separation of wash and green on this boil. Wash, of course, will be returned to fourth boil storage. It would seem that on a seven-boiling system we could expect to get a low pan about every 25 to 26 pans, or from 40 to 48 hours apart.

Table 3 shows the approximate purities of each massecuite in a seven-boiling system:

Table 3.

| Strike Number | Approximate Purity |
|---|---|
| 1 | 98.6 |
| 2 | 96.0 |
| 3 | 93.0 |
| 4 | 90.0 |
| 5 | 83.0 |
| 6 | 72.0 |
| 7 | 60.0 |
| Molasses | 50.0 |

I have a report from Lynn Peterson, Peterson Filters and Engineering Company of Salt Lake City, on experiments conducted at Layton on filtration of raw juice without carbonation.

The possibilities shown by these experiments looked very promising. They were conclusive enough that it was decided to build equipment large enough for next year to filter approximately 400 gallons per hour, which we will run through our pilot ion exchange plant. It is hoped that we can run enough cycles to determine the feasibility of ion exchange filtration without carbonation.

I quote from Mr. Peterson's report:

"The filtration of the raw juice looks more economical than it has in the past, due to a combination of an old concept and newly developed liming and filtration equipment. It has been known for some time that the filtration rate is greatly improved at the iso-electric point. However, the point appeared to be too critical and to vary greatly with the juice so that controlling this point would not be feasible with known liming or carbonating equipment. Further more, the filter rate would be such that an uneconomical number of filters of standard design would be required to filter the juice if limed to the elusive iso-electric point.

"A new type limer, known as the Peterson Vacuum Limer and an improved type rotary leaf pressure filter known as the Conkey Rotary Pressure Filter have features which warranted additional experimentation to determine the feasibility of their combination in solving raw juice filtration.

"Tests using laboratory bench size equipment have just been completed at Layton.

"The data indicates that the iso-electric point, using the vacuum limer is not as critical as first supposed and that the number of filter units, using the new design, is not unreasonable if automatic timing and valve control is contemplated. An optimum iso-electric point for the juice at Layton was established between a pH of 10.6 and 11.5 which could be duplicated, and the filter tests on this juice indicate an economical filter rate. A filter area requirement of 3.0 to 3.5 square feet per ton of beets with not more than two men per shift for the limer and filter station is indicated.

"Ion exchange tests were made in the laboratory on juice clarified by the new combination without colloid formation in the resin beds, and at an exchange capacity comparable with ion exchange on second carbonated juice.

"For comparison of existing filtration equipment with the new filter, table 1 and table 2 are shown. The figures are more to show the over-all status and trend of filtration in beet sugar factories, rather than a detailed quantitative analysis of filter capacities. The trend has been toward filters which could operate on shorter cycles with a reduction of labor. The Kelly replaced plate and frame presses with not only 60 percent reduction in filter area requirement, but with at least a 50-percent reduction in labor. The combination of tray clarifier and rotary drum vacuum filter in conjunction with continuous carbonation replaced the Kellys in most factories, by again reducing the filter area and labor. The Conkey could be used to advantage on first carbonated juice since the tray clarifier could be eliminated and thereby minimize retention time.

**Table 1.**

| | Sq. ft. area per ton beets | Filtering cycle in hours | Time between discharge | Men per shift 2000 ton house |
|---|---|---|---|---|
| First Carb Juice | | | | |
| Plate and Frame | 4.0 to 6.0 | 8 hours | 1 hour Manual | 10 |
| Kelly Filter (Stationary Leaf) | 1.5 to 2.0 | 2 hours | 20 minutes Manual | 4 |
| Clarifier Plus Rotary Drum Filter (Vacuum) | 0.4 to 0.6 | Continuous | | 1 |
| Conkey Rotary Leaf | 1.0 to 2.0 | 1½ hours | 15 minutes Automatic | 1 or 2 |

"The same filtration equipment is considered in table 2, except on raw juice limed to an optimum iso-electric point. All figures, except for the Conkey, are estimates from other tests and observations by the Peterson Filters and Engineering Company.

**Table 2.**

| | | | | |
|---|---|---|---|---|
| On Raw Juice at Iso-Electric Point (Optimum) | | | | |
| Plate and Frame (Est.) | 5.0 to 8.0 | 1 hour | 20 minutes Manual | 20 |
| Kelly Filter (Est.) | 3.5 to 4.0 | ½ hour | 10 minutes Manual | 10 |
| Clarifier Plus Rotary Drum Filter (Est.) (Vacuum) | 1.5 to 3.0 | Continuous | | 2 |
| Conkey Rotary Leaf (Test Data) | 3.0 to 3.5 | ½ hour | 10 minutes Automatic | 1 |

"Preliminary settling tests indicated that a thickener ahead of the rotary pressure filter is feasible. The juice temperature does not exceed 50 degrees Centigrade, and having a high pH, a retention time of only 20 minutes being required, this can be justified by a 30 to 40 percent reduction

in rotary pressure filter area required over that shown in table 2. With this combination, plate and frame presses as "polishers" would be used on the thickener overflow. Activated carbon can also be used here to further improve the color.

"Using the Peterson Vacuum Limer in combination with the Conkey Rotary Leaf Pressure Filter for raw juice clarification, an operating cost of from 10 to 15 cents per ton of beets appears to be possible.

"Scaling up the bench laboratory equipment to pilot size for further investigation in the 1948-1949 campaign is now being prepared."

/signed/ Lynn Peterson

# Measurements of Sugar Yields and Losses of Spreckels Sugar Company

W. A. McCann[1]

EVERY BEET SUGAR CHEMIST is vitally concerned with the accounting of sugar in beets purchased by his company and sugar entering the factory, as well as the various losses incurred during the processing period.

This paper is prepared to show various accounting methods used by the Spreckels Sugar Company in calculating the sugar losses occurring from the time beets are purchased until the processing to granulated sugar is completed.

It is believed that complete evaluation of losses must be made before effective control of losses can be accomplished. Considerable effort has, therefore, been made not only to improve the accuracy of determining the usual "known loss," but also to evaluate the various factors which make up the so called "unknown" loss.

The goal is to be able to say with assurance what has become of every pound of sugar received from the grower. This is admittedly an ambitious program and one that has not yet been fully realized. Nevertheless it is believed that considerable progress has been made.

We shall discuss some of the methods used in improving the accuracy of the customary measurements as well as in measuring some of the losses which are not usually reported.

The items designated as customary measurements are:

1. Beets purchased; 2. sugar entering factory; 3. battery losses; 4. lime flume losses; 5. steffen losses; 6. sugar loss in molasses; and 7. granulated sugar produced.

## Beets and Sugar Purchased

It is obviously very important that these quantities be measured with utmost accuracy, and several precautions are found to be helpful in maintaining accurate work. The two measuring agencies are the beet receiving stations and the tare laboratories, which will be considered in order.

Printing scales are used in weighing the beet trucks at all receiving stations. Tel-autograph, electric communications systems or pneumatic conveyors are used wherever possible for the transmittal of the dirt weight figures from the dirt scale to the truck scale house where the tickets are compiled.

The method of taking the tare sample is extremely important. It was found that systematic errors in this procedure could easily develop unless

[1]Chief Chemist, Mantica Factory.

a rigidly standardized method was adhered to. Study of this problem led to the posting at each station of a large illustrated instruction card (figure 1) covering the right and wrong methods of sampling and reasons behind each prescribed step of the procedure. This is supplemented by personal instruction and inspection from a member of the Chemical Department.

The use of the instruction cards has improved the accuracy of sampling, particularly where new employees are concerned. In addition, it has almost completely eliminated grower complaints regarding the entire procedure.

# INSTRUCTIONS TO SAMPLE MEN

A

A sample of approximately 20 pounds must be taken for each truckload of beets dumped into the hopper. This is to be caught in the sample pan beyond the cleaning screen. The sample will be analyzed by the Tare Laboratory for dirt, trash, crown, and sugar content to determine the basis for payment to the Grower. It is, therefore, of the utmost importance that the following rules be observed, to keep the sampling on a just, impartial basis.

1. TAKE THE SAMPLE WHEN APPROXIMATELY ONE HALF OF THE LOAD HAS PASSED OVER THE CLEANING SCREEN. The middle of the load is the most representative portion; therefore it is the portion which should be sampled.

2. SWING THE SAMPLE PAN IN SO THAT AT LEAST PART OF IT PROJECTS UNDER THE CONVEYOR OR APRON FROM WHICH THE BEETS ARE FALLING. The dirt and trash tend to fall straight down while the beets tend to sail out from the conveyor or apron. Unless a portion of the pan passes under the conveyor or apron, the sample will not be representative of the amount of dirt and trash in the load.

RIGHT WRONG

3. SWING THE SAMPLE PAN OUT OF THE STREAM OF BEETS AS SOON AS IT FILLS. If the pan is left in the stream any longer than necessary to fill it, the beets will begin to pile up and roll off. Every beet which rolls off the pan, drops extra dirt into the pan, which again will make the sample unrepresentative. To take a proper sample, the pan must be swung completely in and out of the stream with a rapid motion and with very little hesitation in the stream.

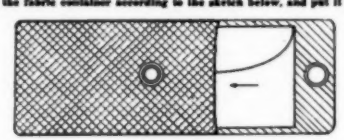
WRONG

4. TRANSFER EVERYTHING CAUGHT IN THE PAN TO A RUBBER-LINED BAG. Just and accurate sampling is governed by the law of averages. A single sample, however carefully caught, may possibly contain slightly more or less tare or sugar than is representative of the load. But in a series of properly caught samples, such chance errors will cancel out, so that the results will be fair. However, if any hand treatment of the sample occurs, such as throwing or shaking off beets, or failing to completely dump the pan into the bag, the law of averages will cease to work and the results will become unjust.

Therefore, do not attempt to doctor the sample in any way. If you have followed steps 1, 2, and 3 correctly, put the entire sample in the bag. If you know that you have made a mistake in catching a sample, the only permissible action is to dump the entire sample out and catch a fresh one.

B

An analysis ticket is made up and placed in the envelope so that it FACES AND LINES UP WITH THE FRONT OF THE ENVELOPE. Enclose it in the fabric container according to the sketch below, and put it inside the sample bag.



1. Hold container with snaps facing you and cover flap at right.
2. Insert envelope with printed side away from you and flap at top.
3. Push envelope in as far as possible without crumpling, then close and snap container cover.
4. Place container with envelope in the bottom of sample bag before dumping in sample.

C

The sample bag is then tied with a double half-hitch and taken IMMEDIATELY to the sample house or bin. Under no circumstances is a sample to be left in the sun after being placed in the sample bag.

## SPRECKELS SUGAR COMPANY

Let us now consider the Tare Laboratory. Warm weather is encountered during the California processing season. The polarization of the tare samples can change appreciably even though stored in rubber-lined bags. Therefore, effort is made to get the samples to the tare laboratories as rapidly as possible. During the 1947 campaign, all but 2 percent of the tare samples were analyzed the same day the beets were delivered.

Taring of the beets is conducted according to a procedure agreed upon by all California growers and processors. Illustrated instructions for procedures are posted at the laboratories. The accuracy of the tare scale work is controlled by saving and weighing all tare material. This weight is checked against the total tares of the individual samples. The weight ratio of crowns to total tare, and the polarization and purity of the crowns are also determined. These figures give a good indication of whether the correct quantity of crown tare has been taken. They also enable determination of the quantity of sugar received in crowns, so that complete accounting for this sugar can be made.

The sugar determination is checked by saving composites of both the pulped beet samples and the polariscope filtrates. These are read by both the main and tare laboratories, and are checked against the ticket averages.

The tare laboratories located in the hot interior valleys are air-conditioned. This minimizes the possibility of dehydration and instrument inaccuracies.

A possible source of error in the tare laboratory is false polarization due to raffinose, amino acids, and other polarizable non-sugars. This was checked during 1944 campaign. The filtrate composites for an entire campaign were analyzed by the double enzyme method of Paine and Balch. The false polarization was found to be a negligible factor in California.

### Measurement of Sugar Entered and Battery Losses

These items are inseparable at two of the factories which have no beet scales. This condition requires that sugar entered be determined as sugar in raw juice plus sugar lost in the batteries.

The customary method of measuring battery losses was found to be inadequate for accurately determining sugar entered. There are two principal reasons for this, one being that the pulp water was assumed to be 100 percent on beets. This has been disproved in calorizator batteries by measurement. The other reason is that exhausted pulp in a single cell was found to vary in sugar content. Therefore, manual sampling of individual cells gave erroneous results, usually low.

The use of continuous pulp samplers on flume pulp was not the total answer to the problem. In order to obtain accurate sampling it was found that the pulp and water must be separated immediately after discharge from the sampler. Unless this is done, water from succeeding samples leaches the previous sample causing serious error. This becomes very important in

flume pulp sampling where the weight of the pulp water is considerably greater than the weight of the pulp.

The separation of the pulp and water is accomplished by allowing the sampler to discharge onto an inclined screen. The pulp rolls off the screen into one container and the water passes through the screen into another container.

It is also necessary to determine the quantities of the pulp and water which are represented by the continuous sample. The ratio of pulp to beets was obtained from marc determinations of the cossettes and of the pulp from the sampler. This ratio was found to be 100 percent for all practical purposes. The pulp being set at 100 percent on beets, a material balance shows that the weight of flume water is equal to the total quantity of water supplied to the battery and pit, less the weight of the diffusion juice.

Therefore, meters have been installed at all plants to measure accurately all waters to the batteries. Then if the analyses of pulp and water are applied to the known weights, an accurate picture of the loss is obtained.

Two factories without beet scales have accurate means of obtaining the weight of raw juice. Beets sliced at these factories are calculated by the following formula:

Let A=weight of raw juice
B=weight of total water to battery and pit
C=percent sugar in pulp water
D=tons of sugar in pulp water or $\frac{C(B-A)}{100}$
E=tons of sugar in raw juice
F=percent sugar in cossettes
G=percent sugar in pulp
H=tons of cossettes or $\frac{100\ (E+D)}{F-G}$

The latter is merely a re-arrangement of the usual formula for obtaining draft by sugar content.

Tons of sugar in pulp$=\frac{HG}{100}$, since the weight of pulp is equal to the weight of cossettes.

The third factory has a beet scale for determination of sugar entered. This factory, however, also uses the above system for determining battery losses, since it has been found much more accurate than any method previously used.

### Steffen Losses

Steffen losses are calculated by applying the percentage of sugar in final waste to the weight of final waste as determined by actual measurements. Both Steffen factories are equipped with continuous recordings weir meters.

Prior to the weir meter installations, the quantity of final waste was calculated by the usual method used where meters are not available. This method depends on the polarization of the various products in the Steffens. Since all saccharates have a definite solubility, excessive dilution of Steffens products, where solid phase is present, can cause an increase in losses without changing these polarizations.

The calculation method, therefore, allows losses due to dilution from excessive wash water, wet steam, foam sprays or other accidents to continue without recognition.

The weir meter installations have not only improved the accuracy of evaluating Steffen losses but have had an appreciable controlling effect in Steffen house operation as a whole. The meters have repaid their cost many times over by quickly detecting excessive dilution in the Steffens.

The laboratory analytical method has been improved by the use of double instead of quadruple dilution, thus doubling the precision of a single determination.

### Sugar In Molasses

Sugar in molasses is determined by direct polarization, since there is little raffinose or other polarizable invert substances in California beets. This was checked for the entire campaign 1944-5 by the double enzyme method. The average difference between the true and apparent sugar was found to be two tenths of one percent.

### Lime Flume Losses and Sugar Produced

These quantities are determined and checked by the usual methods.

### Unusual Known Losses

Having concluded with the usual known losses, we will turn our attention to items making up the so-called undetermined losses. These losses are known to occur and it is believed their magnitude should be evaluated.

Items in this category include:

1. False polarization; 2. sugar losses in transit and storage of beets; 3. diffusion losses in beet flumes and washers; 4. beet tailings and pieces from trash separators; 5. inversion of sugar in process; 6. factory sewer losses; and 7. entrainment losses.

### False Polarization

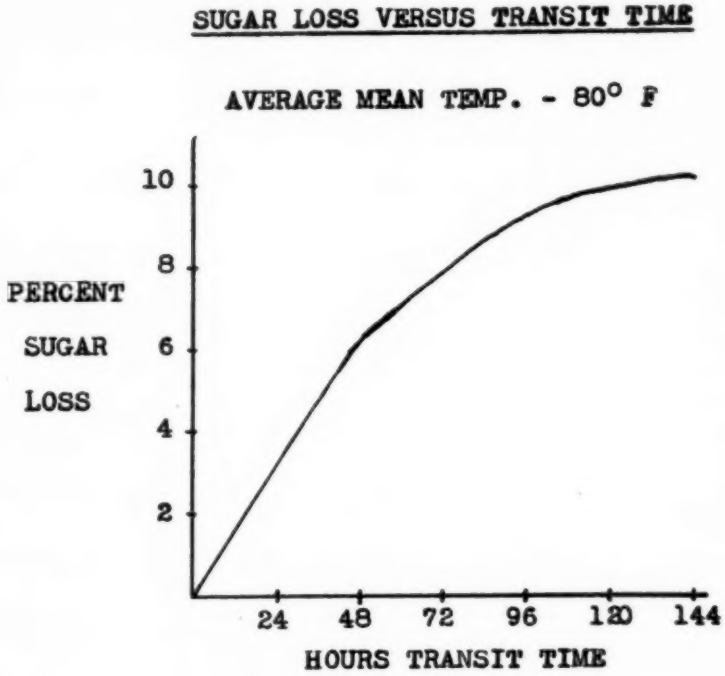
Losses from false polarization were found to be negligible, as previously discussed.

### Transit Losses

The processing of a large percentage of beets hauled by rail at the prevailing high temperatures during the processing period presented the problem of sugar losses occuring in transit from the dumps to the factory.

Early tests of sugar loss in transit were made by having certain cars of beets marked at the dumps for special handling. These cars were to contain no split loads. On arrival at the plants, the cars were weighed before and after dumping, then sampled for percentage sugar and tare. Calculations were made for loss of sugar in transit. It was found impossible to sample the cars accurately, particularly for tare, at the average factory unloading station, so this method was abandoned.

Another method is now used, which appears to give entirely reasonable results. The rate-of-sugar loss in average beets stored at known temperatures is determined by an adaptation of the method of Fort and Stout (3).[2] The data so obtained is then applied to the known conditions of actual transit.




A truck load of beets from a single field is dumped and the beets are segregated according to size. Test samples are then made up so that each contains equal numbers of beets of each size. Samples made up in this manner are found to be very uniform in sugar content. Thus, an accurate measure of weight and sugar loss can be obtained by analyzing some of the samples immediately and storing others in mesh bags under desired test

[2]The numbers in parentheses refer to literature cited.

conditions. If desired, the test samples can be actually shipped in cars, to be recovered, weighed and analyzed on arrival at the factories. It was found that loss rates so determined at one temperature could be applied to other temperatures by means of factors derived from the respiration data of Barr, Mervine and Bice (1) (figure 2).

Having established the average curve for loss versus time at a given temperature, it was possible to apply the test data to the transit times and weather conditions experienced during regular shipments, thus evaluating the actual sugar loss.

### Storage Losses

It is believed that storage losses in the factory bins can likewise be established by placing the test samples at representative locations in the bins. To date, this has not been done, but from experience in determining transit losses by the foregoing method, accurate results are anticipated.

Storage and rehandling losses in piled beets have been established by setting up separate test piles of approximately three thousand (3000) tons. When these test piles were torn down, the beets were loaded into trucks, re-weighed, and re-sampled for sugar content.

### Fluming Losses

All low sugar bearing materials such as main sewer, beet washer, flume washers etc., where inaccuracies may occur due to the very low polariscope readings obtained, are composited with measured amounts of Clerget acid. This serves the dual purpose of preserving the composites and of hydrolyzing the sugar for subsequent determination as invert. Samples handled in this manner may be held for 24 hours before analyzing. The analysis is then consummated by a modified Lane and Eynon method.

The quantity of flume water is determined by the best available method. For example, at Manteca, the flume makeup water is obtained from the overflow from beet washer, oliver condenser and spray lines from the picking table. All these sources of water are equipped with measuring devices or constant flows have been calibrated. The flume water entering the factory and the discharge from the beet washer are sampled every hour.

Direct determination of sugar in the flume water is impossible at one factory because a portion of the pulp water is used for fluming beets. In this case, an indirect determination of fluming losses is made. The average immersion time is determined by placing painted beets in the flume. A weighed sample of representative beets is then placed in a known weight of water at fluming temperature, which is agitated for the proper time. The rate of sugar loss is obtained from the increase in polarization of the water.

### Beet Tailings

The beet tailings and accumulated trash from the trash catchers are sold by weight at one factory. Regular samples are taken of this material, prepared in the same manner as cossettes and polarized. It only remains to

calculate the sugar loss by weight. Sampling of this material is somewhat of a problem, but by diligent quartering of a large sample, good results are obtained.

The beet tailings and trash are disposed of by disintegration at the other factories. This poses a problem in quantity determination. The solution was found in measuring the flow of fresh water which was used to flush the trash through the disintegrator. Since the trash was reasonably well drained before mixing with the water, the free liquid in the disintegrator effluent could be considered equal in quantity to the fresh water applied. The disintegrator effluent is therefore sampled regularly, and it's free liquid content is determined by passing the sample through a 20-mesh screen. The quantity of the effluent is then taken as the quantity of fresh water added, times 100, divided by the percentage free liquid in the effluent.

Percentage sugar in the effluent is determined by digesting a portion of the sample at 80 degrees Centigrade for 30 minutes. This establishes the equilibrium between the solid and liquid phases, and is followed by cooling, dry lead clarification, and polarization.

## Factory Inversion

It is considered that all invert found in the molasses has come from sugar decomposed in the process. This is believed practically true on the grounds that the small amount of invert passing the carbonation is subsequently destroyed. Tests are now being made on the accuracy of this assumption.

Inversion prior to carbonation may be determined by comparing the invert analysis of the cossettes and the raw juice. This has not yet been undertaken.

A modified Lane and Eynon method is used for all invert determinations.

The possibility of applying the method of Davies, Yearwood, et al (2), was also tested. This method appeared to offer good possibilities for determining losses of sugar by decomposition in the factory. It consisted of determining the ratio of sugar to chloride in the various processing phases. A simple titration method for chloride was presented, which could readily be adapted to routine work.

Unfortunately it was found that the beet factory juices contained appreciable amounts of un-ionized organic chlorine. The ratio between ionized and un-ionized chlorine was found to change as the juice progressed through the factory. Thus the simple titration was unusable. The A.O.A.C. carbonated ash method and the Carius method for chlorine were found too tedious to run the large numbers of samples required. Therefore the project was abandoned.

A method has been developed, however, for determining the sugar decomposition in any given phase of the process with great accuracy. The time temperature conditions of the process in question are reproduced on

the laboratory bench by means of a series of jacketed coils and closed vessels. Representative samples of juice are forced through this system under pressure at the correct flow rate. The juice flows through a heat exchanger, cooling it to room temperature, before it emerges from the system. The system being hermetically sealed, there is no weight change of the flowing juice.

The simple analysis of the juice, before and after passage through the apparatus, therefore, gives directly the loss of sugar.

### Factory Main Sewer Losses

The method of determining the sugar concentration in sewer samples has already been discussed.

Methods have been found at each factory for measuring the flow of all waters to the main sewer by the use of a system of manometers, weirs and pitot tubes. Flume and Beet Wash effulents are also measured. One factory has a removable weir which is lowered into the sewer flume at frequent intervals.

Another factory meters the cold water entering, and deducts from this the known quantities of water discarded at points other than the sewer. This procedure is facilitated by the concentration of all Steffens waste and the recirculation of the condenser leg waters over a cooling tower. The quantity of pulp flume water is determined as previously described, and the amount of lime flume water is readily obtained from the CaO balance.

### Entrainment Losses

These losses generally are of a minor nature. Continuous samplers on all condenser leg lines are used for control at all plants, and any continuity of sugar loss is thoroughly investigated. Sugar entrainment to evaporator condensates used in boiler feed are controlled by patented sugar detectors.

### Reporting of Losses

The venturesome step has been taken of reporting on the extraction statements not only the usual known losses, but also the other losses which can reasonably be determined by the above methods. It is believed that several important results have been achieved:

1. The unaccountable losses have been reduced to a very low figure.
2. It is becoming much easier to place a value on such formerly nebulous items as improved rail service, rapid handling of beets through the bins, shortening of flumes, reduction of juice retention time in process, etc.
3. Actual reporting of these losses has been a great stimulus to developing, simplifying and improving the accuracy of the methods used.
4. Isolation and presentation of all possible sugar losses has created a co-operative spirit among the operating personnel regarding undetermined losses that might otherwise be undetected.

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(1) BARR, MERVINE AND BICE.
1940. Proc. Amer. Soc. Sugar Beet Tech., pp. 52-65.

(2) DAVIES, YEARWOOD, ET AL.
1942. Sugar, 37, No. 12, pp. 29-33.

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U.S.D.A., Agricultural Chemical Research Division, Contribution No. 177.

# Some Studies on Continuous Carbonation

R. A. McGinnis[1]

A NUMBER OF YEARS AGO a study was initiated by the research department at the Woodland factory of the basic variables of Dorr system continuous first carbonation from a strictly empirical viewpoint. The purpose of these studies was primarily to determine the optimum setting for the best possible quality of thin juice. Some of this material has been published previously (3),[2] and this paper will partake in part of the nature of a review.

In 1939 Professor Dedek published a paper (2) in which he propounded the thesis that any experimental results pertaining to the processing of sugar are valid only for the particular beets concerned, and he supported this thesis with very convincing data; as a result we must specify that the results here reported are essentially valid only for the particular raw materials that were used. Most of the work was carried out with diffusion juice derived from fresh beets. Some of the diffusion juice, however, was obtained from dried cossettes. Much of the work reported has since been checked a number of times, and we can say safely that while the work was carried out with differing raw materials and is strictly valid only for them, nevertheless the general qualitative picture presented seems to hold true for almost any raw materials we have met with in the central California area.

## Apparatus and Methods

After some experience with pilot plant scale apparatus, the conclusion was quickly reached that the work would be most advantageously carried out with bench-scale equipment. Over a considerable period of time an apparatus was developed which, through close imitation of the full-scale equipment, produces a thoroughly characteristic first carbonation juice, even to the settling properties of the mud (figure 1).

A method was developed for studying the settling properties of first carbonation mud, based on the procedure of Coe and Clevenger (1, 3), which has given very satisfactory results.

Second carbonation was carried out in a standardized fashion to individually determined optimum end-points. Reference is made to the publication (3) for complete experimental details.

## Factors Affecting Dorr First Carbonation

The most important factors are, pH or alkalinity, temperature, amount of lime, rate of recirculation, retention time, and rate of gas absorption. These will be discussed individually, presenting our own data when occasion offers and summarizing our own current practice.

[1]Head Research Chemist, Spreckels Sugar Company, Woodland, California.
[2]The numbers in parentheses refer to literature cited.

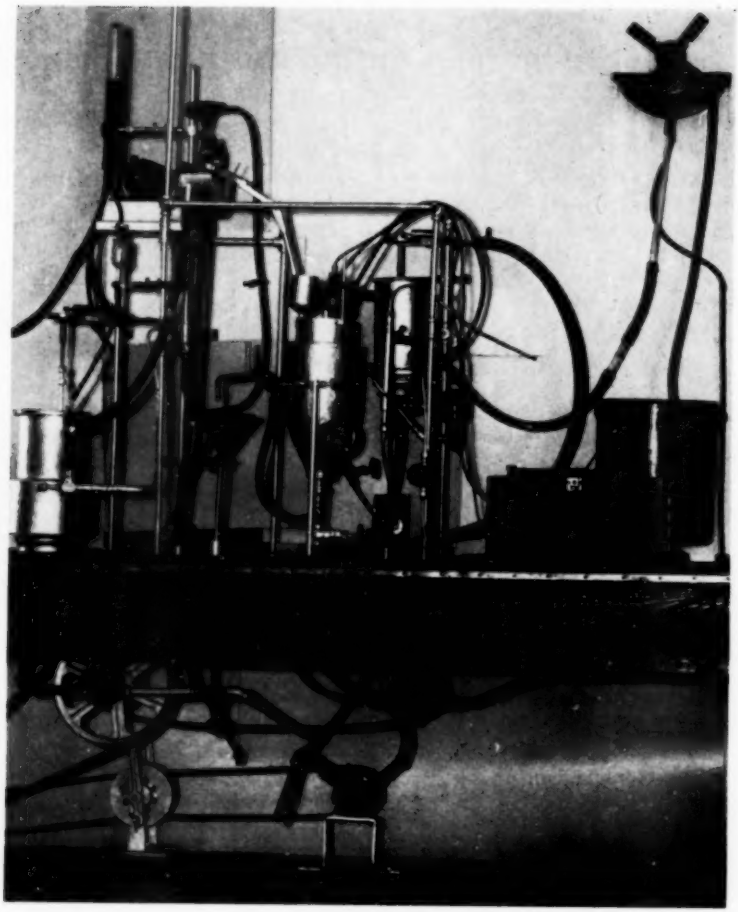

Figure 1.—Bench-scale Dorr system first carbonation apparatus, used in obtaining the data reported.

### 1. *pH or Alkalinity*

The traditional control analysis in first carbonation has been the alkalinity, expressed in grams of CaO per 100 cc. of filtered juice. This analysis has had the disadvantage that it is a titration (see another paper to be presented at this meeting).

The Dorr system almost invariably uses a continuous indicator of the first carbonation end-point, and very frequently automatically controls the end-point. Originally control was by conductivity measurement. This was

generally found unsatisfactory for several reasons. In the first place the electrodes tended to scale very rapidly, resulting in a continued drift in what should have been a constant reading. This drift, however, could be allowed for. More serious is the fact that conductivity measurements are in general far too insensitive for satisfactory control. In addition, the conductivity is frequently affected by variations in concentration of substances other than desired ions.

In the early thirties it was discovered that the antimony electrode could apparently be used successfully in measuring pH in hot liquids, and has very largely replaced the conductivity apparatus. The antimony electrode has, however, been shown to have serious faults as a pH measuring apparatus. Scaling is not serious, as with the conductivity apparatus, but a film does form over the antimony electrode which must be polished off at least every 8 hours. The voltage produced varies with the velocity of the liquid flow past the electrode. Also the electrode is readily poisoned by certain chemicals which are sometimes present in the juices, and at such times gives false measurements.

A few years ago, Dr. A. O. Beckman introduced the hot glass electrode, which is far more sensitive than the antimony electrodes, and is free from the above mentioned faults. Many installations have been made with considerable success.

It was early found at Woodland, however, that while a measurement of pH is quite satisfactory for control, the controlling pH must be set to give the alkalinity desired. As is known,

$$pK_w = pOH + pH$$

| Temp. °C | $pK_w$ |
|---|---|
| 80 | 12.55 |
| 90 | 12.34 |

Since $pK_w$ varies with temperature, the relation between pH and pOH must also vary with temperature.

An example will be given. While we do not know the precise values of $k_w$ in first carbonation juice, we may take the values for pure water as a first approximation. Thus, if carbonation is being operated at 10 pH and 80° C,

$$12.55 = pOH + 10.00, \quad pOH = 2.55$$

This means that the concentrations of the two ions are,

$$(H^+) = 0.000\,000\,000\,1$$
$$(OH^-) = 0.003$$

At 90° C, however

$$12.34 = pOH + 10.00, \text{ or } pOH = 2.34$$

and while the concentration of $H^+$ is the same, $(OH^-)$ has increased to 0.005.

While the pH measuring equipment is measuring the concentration of hydrogen ions, it is apparent that it is the hydroxide ions which must be affecting the reactions in defecation. If the temperature remained constant a measurement of pH would suffice for a measurement of pOH. If the temperature changes, however, it is clearly no longer sufficient. In figures 2 and 3 are shown the relationship of pH and of pOH with the alkalinity of first carbonation at various temperatures, for a number of data taken from many types of materials, using saccharate milk defecation. Other factors also change the relationship between pH and pOH, such as variations in the nature of non-sugars, variations in the amount of lime used, and variations in the density of the diffusion juice.

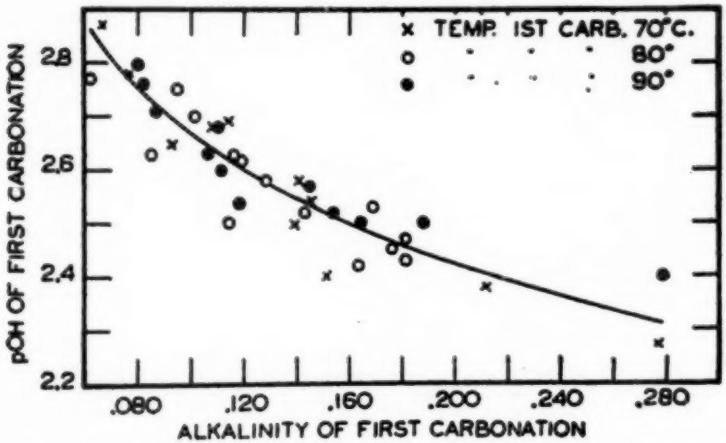


Figure 2.—Relation between pH and alkalinity of various first carbonation juices at indicated temperatures.

There is no practical method, as far as is known, for continuously and directly measuring the hydroxide ion concentration. Alkalinity titrations, however, are very close to being proportional to such measurements. The best proof of this statement is empirical. Apparently the bulk of the alkalinity is free, and the part that is bound is roughly constant.

Thus, until a practical electrode for measuring hydroxide ion directly shall have been found, titrateable alkalinity must be considered the best control measure for first carbonation. At the present time this can best be effected by making frequent alkalinity titrations and resetting the pH control point to give the desired alkalinity.

The second consideration under this heading is what alkalinity to choose for the first carbonation end-point. Our work showed that the

higher the alkalinity, up to a certain point, the better the quality of the thin juice produced, as measured by its lime salts, color and colloids content (figures 4, 5, 6 and 7). The "certain point" is about 0.130 for saccharate milk defecation and between 0.100 and 0.120 for milk of lime defecation. On the other hand, the lower the alkalinity, the more easily the carbonation mud can be filtered and settled out, as will be shown later. As a result, the alkalinity chosen is a compromise, depending upon the capacity and efficiency of the mud separation apparatus.

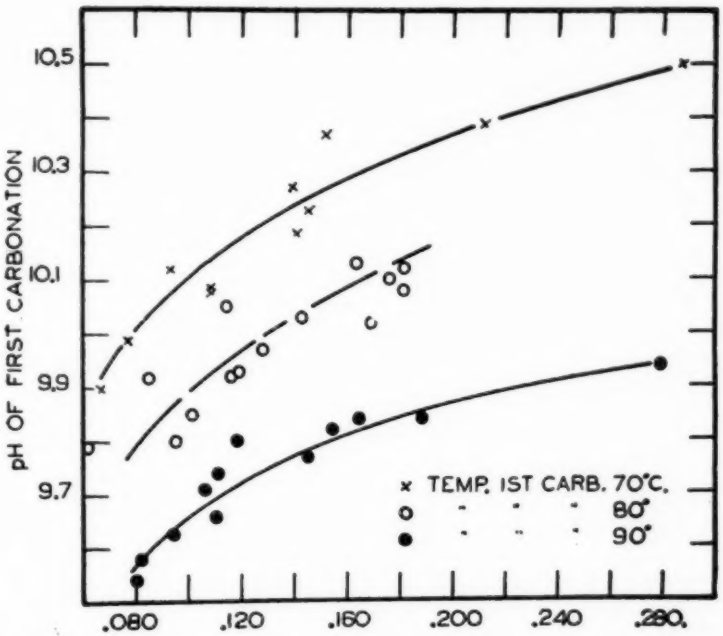


Figure 3.—Relation between pOH and alkalinity of various first carbonation juices at indicated temperatures (same data as figure 2).

2. *Temperature*

The higher the temperature is carried in first carbonation, the easier is the settling and filtration of the mud. As before, however, the worse it is for juice defecation, as shown by the foregoing figures. Once again a compromise must be made.

3. *Amount of Lime*

Studies have been made on the effect of the amount of lime used, both at normal operating alkalinities and at the optimum alkalinities for best juice quality.

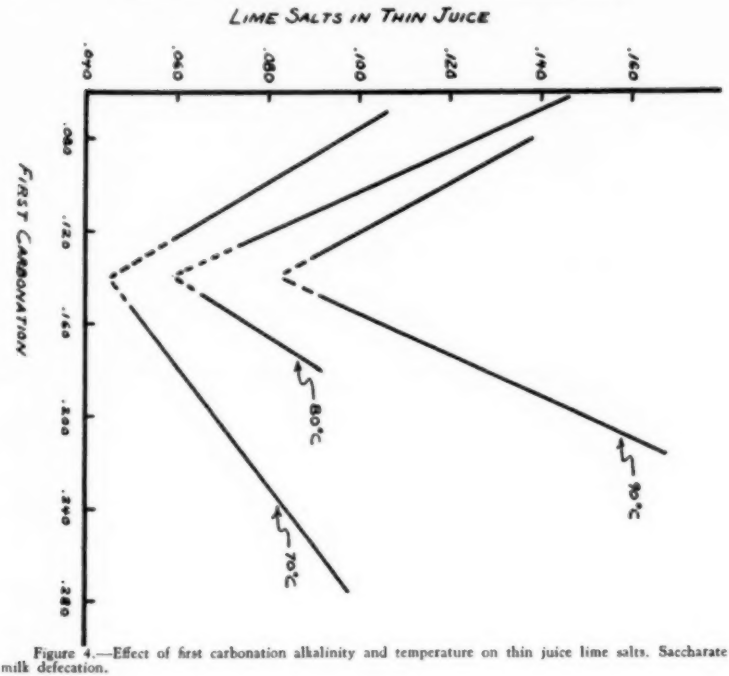


Figure 4.—Effect of first carbonation alkalinity and temperature on thin juice lime salts. Saccharate milk defecation.

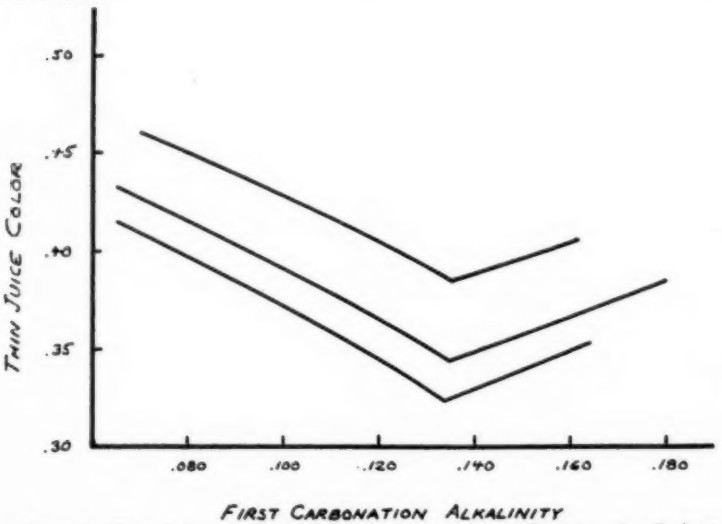


Figure 5.—Effect of first carbonation alkalinity and temperature on thin juice color. Saccharate milk defecation.

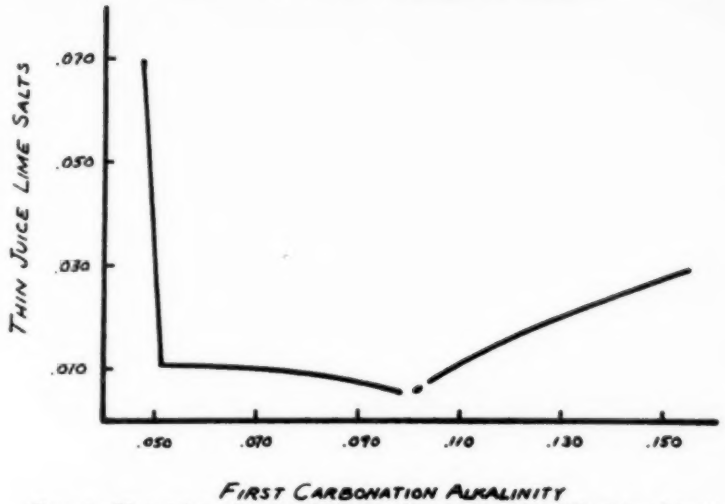


Figure 6.—Effect of first carbonation alkalinity on thin juice lime salts. Milk of lime defecation at 80°C.

Figure 7.—Effect of first carbonation alkalinity on thin juice lime salts. Milk of lime defecation at 80°C.

Figures 8, 9, 10, and 11, show that at normal alkalinities, the greater the amount of lime used, the better is the thin juice quality, up to at least 5.5—6.0 percent CaO on beets, which was the limit of the tests. An exception is found at very high lime addition with prediscard saccharate milk, where the lime salts content increases. There appears to be no confirmation of the belief sometimes voiced that only very small amounts of lime are required for adequate defecation, the major portion of the lime being useful only as a source of filter aid.

The defecation efficiency decreases with large lime additions, in most cases. Definite decreases may be said to become appreciable above the following approximate percentages of lime on beets.

**Table 1.—Defecation efficiencies with increasing lime additions.**

| Type defecation | Alkalinity | —with respect to— Color | Lime Salts |
|---|---|---|---|
| Saccharate milk | .080 | over 6 percent | over 3.5 percent |
| | .130 | over 2 percent | over 3.5 percent |
| Milk of lime | .080 | over 3.6 percent | over 3.0 percent |
| | .100 | over 2.3 percent | over 2.3 percent |

At the optimum alkalinity for thin juice quality, the effect is the same, excepting that the defecation efficiency is much greater.

**Table 2.—Defecation efficiencies with increasing lime additions at optimum alkalinities.**

| Type defecation | Percent of normal lime addition at .080 alkalinity necessary to obtain equivalent value at optimal alkalinity | |
|---|---|---|
| | Color | Lime Salts |
| Saccharate milk | 35.5 percent | 63 percent |
| Milk of lime | 59 percent | 74 percent |

At the optimum alkalinity with both types of defecation there is indication that a lime salts value of about 0.016 represents probably the lowest value that we can hope to attain with central California beets.

The point at which the juice quality improvement does not justify the cost of additional lime, must, of course, be individually determined for each factory.

The actual amounts of lime required to obtain adequate defecation vary with many factors, chiefly the amount and nature of the non-sugars. There are localities in which the beets are of such high purity that relatively little lime is required. For example, excellent defecation has been secured with lime additions as low as 1.1 percent CaO on beets, with comparatively high purity diffusion juice. On the other hand, in another section, 2.5 percent CaO on beets is required with a comparatively low purity raw juice.

*4. Rate of Recirculation*

What few studies we have made of this variable tend to confirm the recommendations of the Dorr Company. The rate is ideally 7:1, but apparently can vary within 5:1 and 9:1 without undue disadvantage.

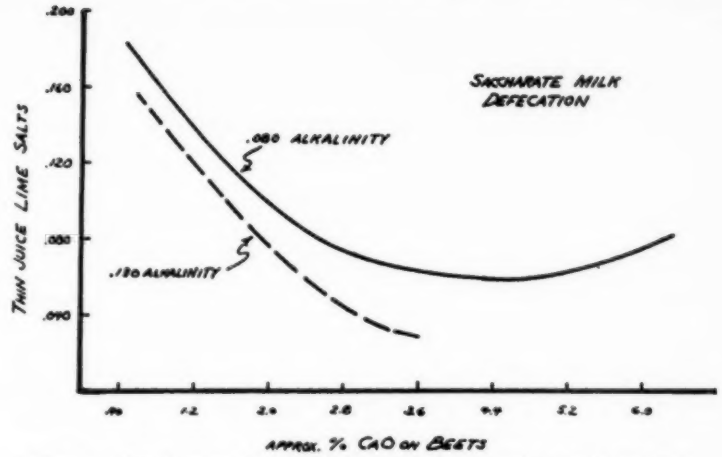


Figure 8.—Effect of amount of saccharate milk on thin juice lime salts. Standard conditions.

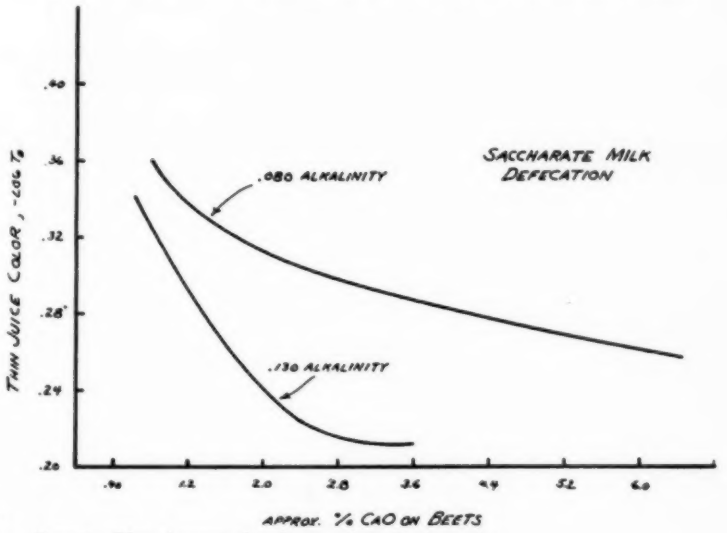


Figure 9.—Effect of amount of saccharate milk on thin juice color.

### 5. *Density of Diffusion Juice*

Data which will not be presented in detail at this time have shown that as the concentration of dry substance in the diffusion juice is increased, the proper end-point alkalinity for operation also increases. Thus, a thin juice of very irregular quality will result if care is not taken to keep the

raw juice density constant. However if the optimum alkalinity is maintained in spite of change, the defecation is somewhat more efficient at higher densities, at least with respect to lime salts. Considering both this fact, and the cost of evaporating water, it is apparent that it is advantageous to carry as high a diffusion juice density as possible without increasing battery losses.

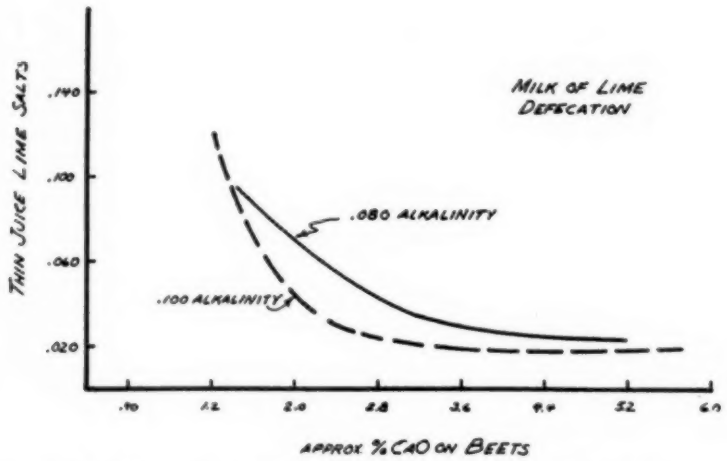


Figure 10.—Effect of amount of milk of lme on thn juice lime salts. Standard conditions.

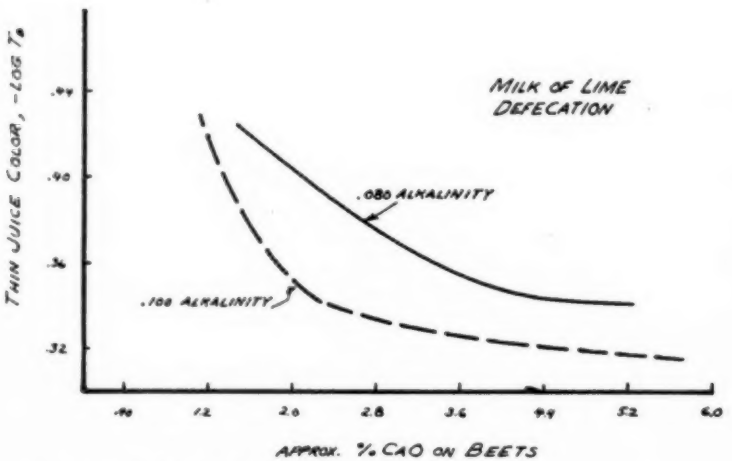


Figure 11.—Effect of amount of milk of lime on thin juice color.

*6. and 7. Rate of Gas Absorption and Retention Time*

As our studies have not yet adequately covered these subjects, we will merely mention them.

## Importance of Smooth Operation

As was stated, the best setting for the operating variables in first carbonation is a compromise between good thin juice quality and ease of mud separation. The best operating alkalinity is as high a one as possible, without interfering with settling or filtration.

Due to irregularities in various factors, it is never possible to maintain an absolutely constant alkalinity. The magnitude of the irregularities determines how high the alkalinity can be carried. For example, if in a given factory the Dorr overflow becomes seriously cloudy at 0.100 alkalinity, and the magnitude of the irregularity is of the order of 0.020 units, then 0.080 is the highest alkalinity that can be safely carried. If the irregularity is reduced to 0.010, then 0.090 alkalinity can be aimed for, with a much better quality thin juice produced.

Thus, if first carbonation is to be operated at its maximum efficiency, all the variables must be smoothed out as far as possible to reduce the magnitude of the irregularities. Among these variables are raw juices density, temperature and rate of flow, carbon dioxide gas pressure and $CO_2$ content, saccharate or milk of lime density and flow rate, and quality of burned lime.

*1. Raw juice density.* In order to achieve even density smooth battery operation is essential. Due to the fact that the juice density unavoidably changes within each draw of juice, there should be enough capacity in the raw juice tanks to even the density out. Those fortunate factories possessing continuous batteries do not have any worries on this score.

2. *Raw juice temperature.* It is possible by careful operation of the raw juice heaters to keep the temperature fairly uniform.

3. *Raw juice rate of flow.* This factor is a very important one, and its control is much easier if the raw juice receiving tanks are of adequate size. Some satisfactory type of flow meter should be used such as a Root-Connersville meter or an orifice meter to measure the flow to the primary tank. If the rate of flow does vary, the saccharate or milk of lime flow rate should vary with it.

4. *Kiln gas pressure.* This pressure should be constant to at least 1 percent of the nominal gauge pressure for really smooth control. Since variation of the gas pump speed will frequently interfere with lime kiln operation, some form of pressure controller independent of the gas pump, close to the carbonators, is indicated.

5. *Carbon dioxide content of kiln gas.* This is a factor that is frequently ignored, but it is just as important as the gas pressure. Large varia-

tions in the percentage of $CO_2$ are ordinarily due to leaks in the kiln. A common cause is the kiln door failing to close entirely after a charge of rock. A continuously recording carbon dioxide analyzer is a great help to both kiln and carbonation operators.

6. *Saccharate or milk of lime density.* Unless the density of the milk is constant, carbonation operation will be very irregular. This station frequently does not receive the attention it deserves, considering the importance of the uniformity of its output. The installation at Woodland has an automatic control in the form of a Foxboro density controller.

7. *Saccharate or milk of lime flow rate.* Although in many factories the lime milk flow is merely controlled by a valve, scaling in such installations is so rapid that a constant flow rate cannot be maintained. Much better results are obtained with feeders of the bucket wheel type.

8. *Quality of burned lime.* If the burned lime rock is not constant in its CaO content, constancy of milk density will obviously not suffice.

## The Clarifier

Normally, retention times in the clarifier of from 1½ to 3 hours are found. The dilute juice cannot be held at appreciable alkalinities and at advanced temperatures for such lengths of time without undergoing some form of degradation. This degradation has been determined for a number of different juices, and the average magnitude from many determinations is shown in figures 12 and 13. Thus, at normal alkalinities, and at 80 degrees centigrade, increases of about 7 percent in color and 0.010 in lime salts per hour were found for juice defecated with saccharate milk. The degradations are decreased as the alkalinity becomes higher. With milk of lime defecation, the degradation is also much less.

In addition to its normal mechanical adjustments, the clarifier is affected by the following variables: temperature, alkalinity of first carbonation juice, amount of lime used, density of first carbonation juice, form in which lime is used, and percentage recirculation in first carbonation.

1. *Temperature,* has an important effect on the rate of sedimentation of the mud through its effect on the viscosity of the liquid phase. This factor is quite an appreciable one, and is thoroughly understood.

2. *Variation* of the alkalinity of the first carbonation juice has a very important effect, which requires preliminary explanation. It is apparent that in the clarifier, mixtures of mud and juice may be found of any composition between the rather dilute mixture entering as feed to the rather concentrated mixture leaving as underflow. Examination of the settling properties of these materials, by the modified Coe-Clevenger method previously mentioned shows that the overall settling rate is fixed by the slowest settling rate found in any of these possible mixtures (figures 14). Thus, in

one instance the slowest rate of settling might be found in the most dilute mixture of mud and juice, corresponding to the composition of the feed material; in another instance the slowest rate might be found in the most concentrated mixtures, corresponding to the composition of the underflow; and in a third instance the slowest rate might be found in an intermediate mixture. For convenience in reference, we have termed these three types A, C, and B, respectively. As far as operation is concerned, it is apparent that increasing the stroke of the mud pumps and consequently lowering the density of the underflow will not increase the clarity of the materials in cases of type A materials, but that a very positive advantage will be obtained in type C materials.

The alkalinity of first carbonation is one of the most important factors in determining the type (figures 15 and 16). At low alkalinities with normal juice densities the materials are almost invariably of type A. As the alkalinity is raised the curves go through the intermediate type B, reaching type C in the vicinity of 0.085 to 0.100 alkalinity. As a rule type C materials settle more slowly than type A materials, so that the overall settling rate, and the size of the clarifier required increase almost steadily with increase in alkalinity.

However, if there is ample mud filter capacity, and difficulty is being experienced with turbid overflow, it may frequently be advantageous to raise the alkalinity to the point at which a type C curve is obtained, so that the turbidity may be decreased by drawing out the underflow more rapidly.

3. The *amount of lime used* affects the settling in two ways. In the first place, if the amount of beets sliced remains the same, the amount of mud is increased. In the second place, the curve type is changed, there being a tendency to shift toward the A type of settling curve with increasing amounts of lime. In general, the sum of these effects is to retard the overall settling rate somewhat with increasing amounts of lime (figures 17, 18, 19 and 20).

4. The *density* of the first carbonation juice has an effect on the settling type of the material. The alkalinities required to give the same type of material are higher if the density of the juice is raised. A second effect is the increase of the viscosity of the juice obtained with increase in density. If the volume of diffusion juice flow is kept constant as its density is increased, larger settling capacity is required. However, if the weight of dry substance entering carbonation in unit time is unchanged, settling is somewhat more rapid with increase in juice density.

5. Whether the lime is added to first carbonation juice in the form of milk of lime or saccharate milk makes quite a difference in mud settling rates. Milk of lime, in general, yields a more difficultly settling mud.

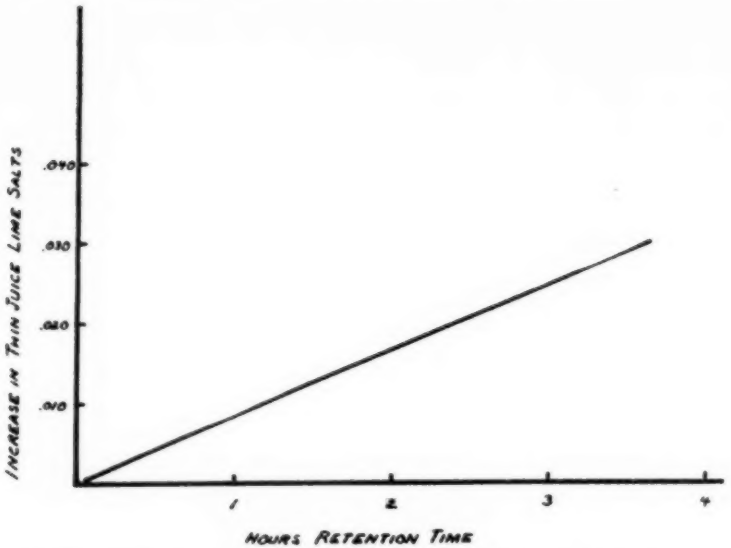


Figure 12.—Effect of time in clarifier on thin juice lime salts. Saccharate milk defecation.

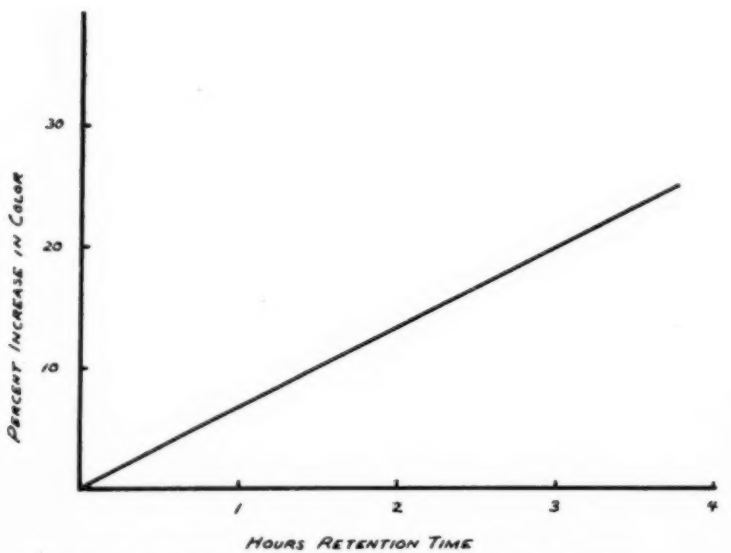


Figure 13.—Effect of time in clarifier on thin juice color, Saccharate milk defecation.

6. The *percentage recirculation* in first carbonation has a very great effect. Without recirculation or its equivalent it is not possible to clarify by settling. This is due to the fact that clumps of granules are said to be built up by recirculation (figures 21 and 22).

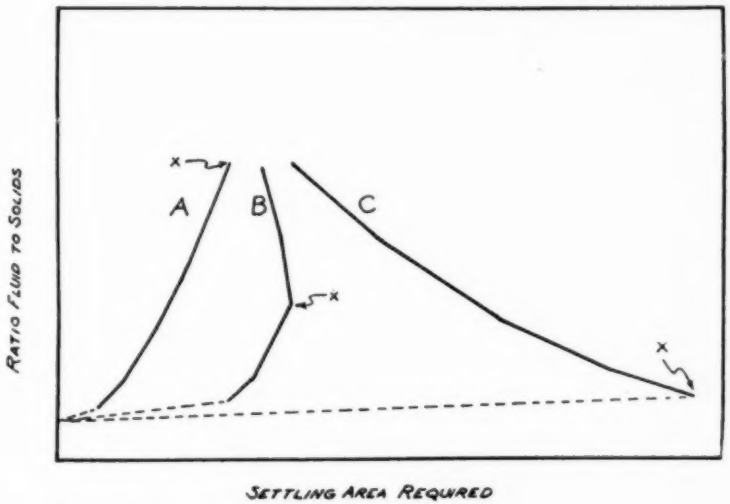


Figure 14.—Three types of first carbonation mud settling curves.

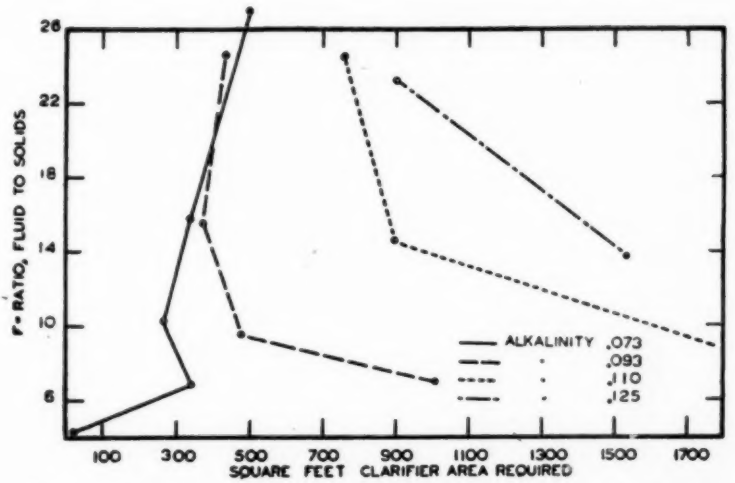


Figure 15.—Effect of first carbonation alkalinity on mud settling curves. Saccharate milk defecation.

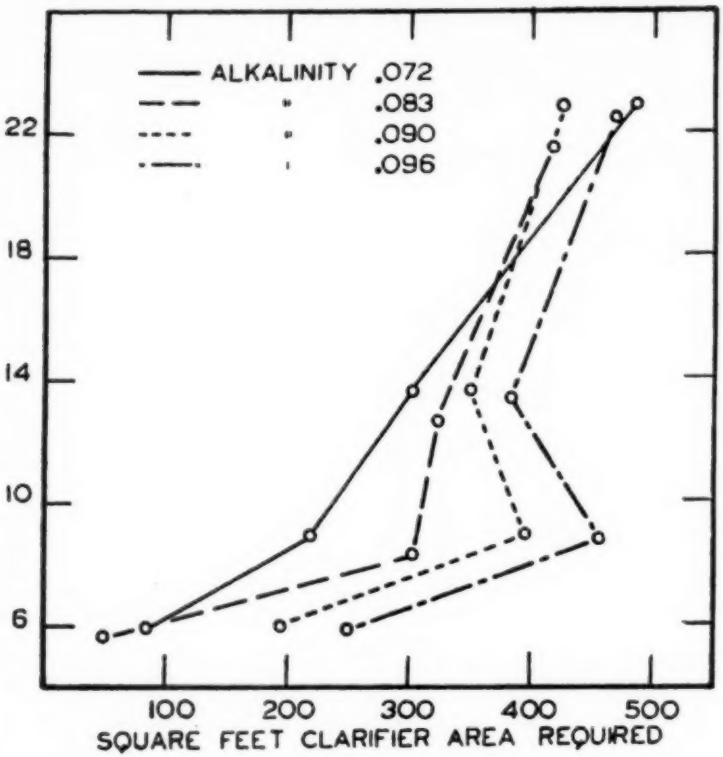


Figure 16.—Effect of first carbonation alkalinity on mud settling curves. Milk of lime defecation.

*Effect of Clarification on the Juice*

To be successful, the overflow from the clarifier must be reasonably clear. If it cannot be made so, it must be subjected to an auxiliary pressure filtration, and much of the savings made possible by the use of the clarifier are lost. Actually, appreciable amounts of mud can be tolerated in the overflow without causing appreciable degradation of the thin juice. The process was designed to yield an overflow containing not more than 0.0025 percent dry mud on the weight of juice. Experiments have shown us that at least 10 times that amount of mud can be tolerated without producing any measurable degradation. A better juice will in general result from operating with a very slight degree of turbidity and a high alkalinity, rather than with a lower alkalinity and a perfectly clear overflow.

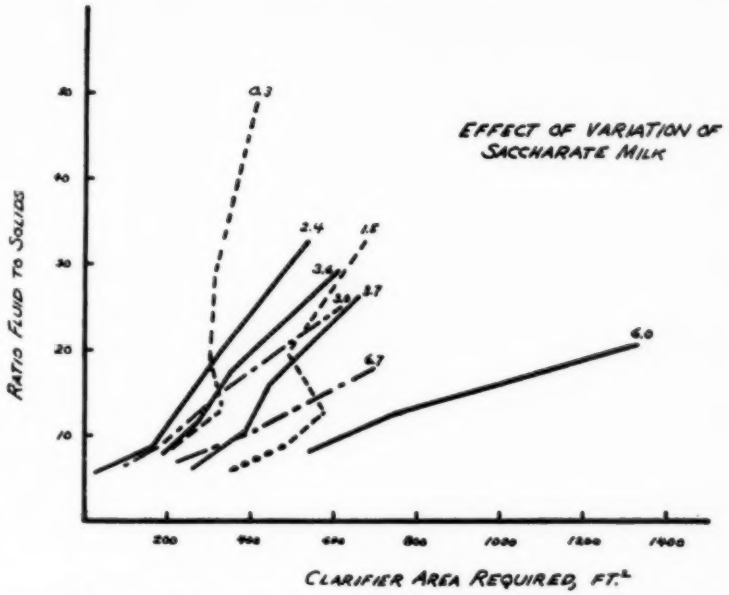


Figure 17.—Effect of varying amount of saccharate milk on first carbonation mud settling curves.

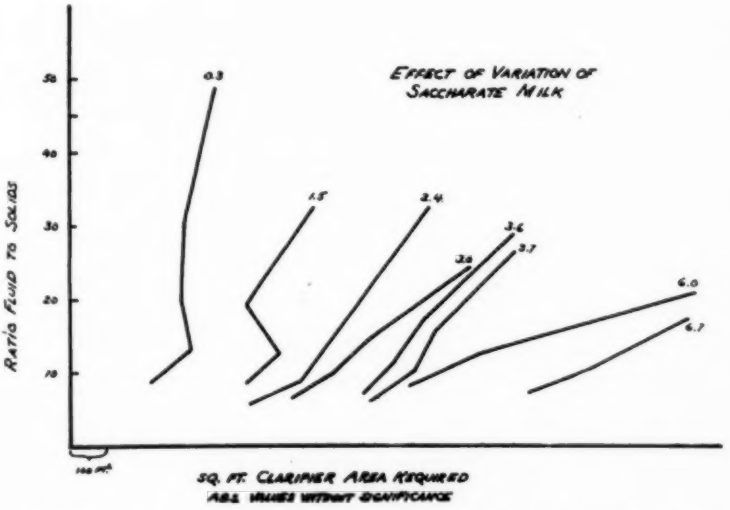


Figure 18.—The curves of figure 17 displaced along the X axis to show the change of curve shape with amount of saccharate milk.

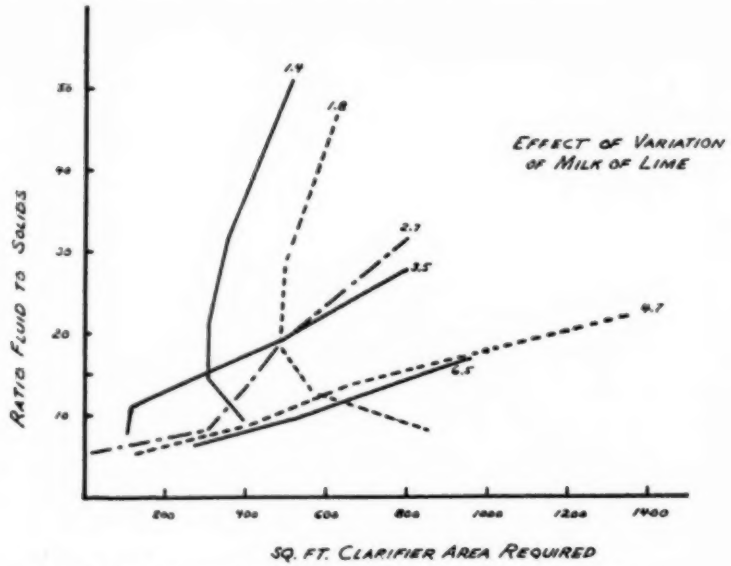


Figure 19.—Effect of varying amount of milk of lime on first carbonation mud settling curves.

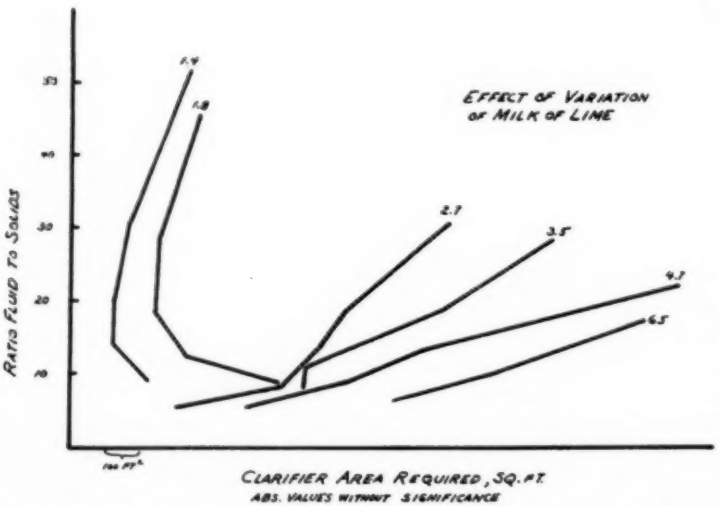


Figure 20.—The curves of figure 19 displaced along the X axis to show the change of curve shape with amount of saccharate milk.

*Comparison of Continuous with Batch Carbonation*

We have seen that many compromises must be made in adjusting the various variables of continuous first carbonation to their optimum operating positions. The whole system seems to us to be, in itself, a great compromise, in which there is some sacrifice in juice quality to make available the great savings in labor and materials over the batch system.

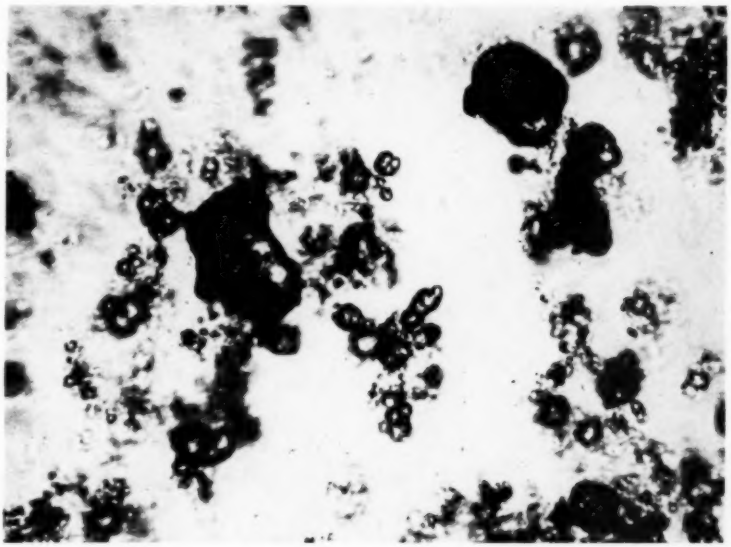

Figure 21.—Microphotograph of Dorr system first carbonation mud. Note clumps of calcium carbonate particles. x 1000.

Following are the results of four tests, in which direct comparisons were made between continuous and batch carbonation. In each of these tests factory raw juice was used as well as factory saccharate milk. Each sample of raw juice was divided into two parts, and one part then processed by the continuous method and the other by the traditional batch method. The same amount of lime was used in each, the same terminal alkalinities (about 0.080), the same temperatures (80° C.) and the same retention times (27 minutes). Second carbonation was identical for both.

In table 3 is given the percentage of lime salts, color and colloids in the thin juice resulting from continuous carbonation.

Thus on the average, the continuous system of carbonation produced 43 percent more lime salts, 67 percent more color, and 21 percent more colloids than the batch method.

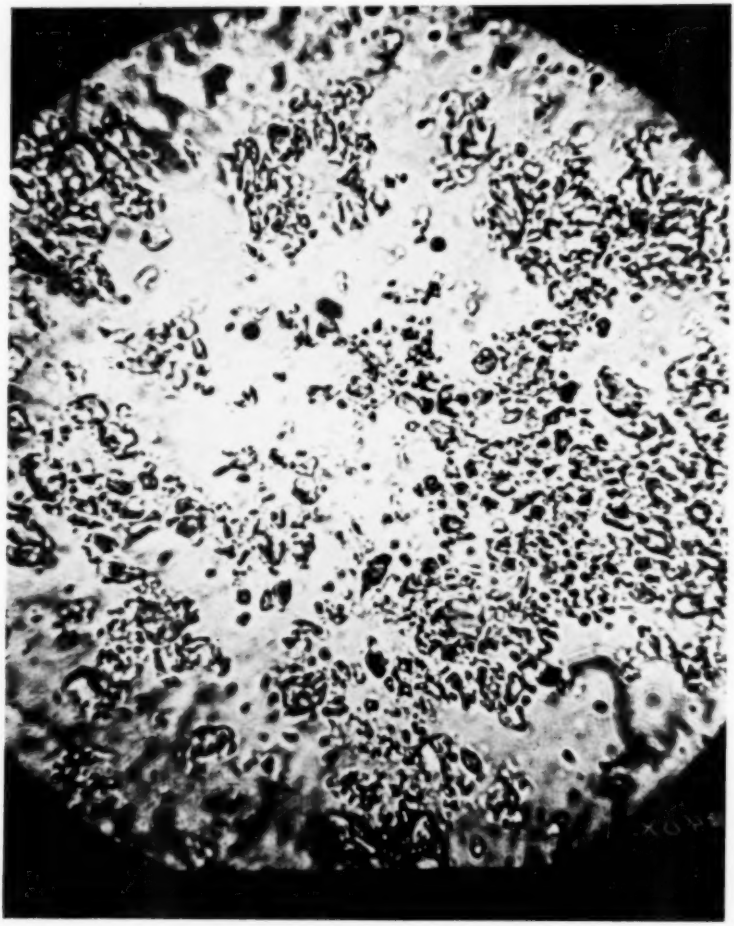

Figure 22.—Microphotograph of first carbonation mud produced by standard batch system defecation. x 1000.

As a further matter of interest, the final second carbonation juices from each of the parts of test 4 were sulfured with 0.007 percent $SO_2$ on 10 RDS juice, and were then concentrated for 1 hour under vacuum to 1/3 the original volumes. The samples were then diluted back to 10 RDS and their transmittancies redetermined (table 4).

These results indicate that within the limits of error the color of batch carbonation juice does not increase more rapidly in the evaporators than that from continuous carbonation.

**Table 3.—Percentage lime salts, color and colloids in thin juice from continuous carbonation calculated on the results obtained from batch carbonation.**

| Test No. | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|
| Lime salts | 138 | 168 | 138 | 126 | 143 |
| Color | 155 | 143 | 200 | 168 | 167 |
| Colloids | 121 | 97 | 97 | 168 | 121 |

**Table 4.—Comparison of colors of thin and thick juices originating in batch and continuous carbonation.**

| | Continuous | Batch | Difference |
|---|---|---|---|
| Color, thin juice | .342 | .204 | .138 |
| Color, after adding $SO_2$ | .317 | .189 | .128 |
| Color, thick juice | .348 | .214 | .134 |

*Centrifugal Separation of First Carbonation Mud*

In an effort to move the balance point of this compromise further toward the side of better juice quality, an adaptation of the process was contemplated which, if it had been successful, would have eliminated the clarifier retention time and enabled operation of first carbonation to be carried out at the optimum alkalinity for juice quality.

A pilot plant was set up and arrangements made for experiments to be conducted in cooperation with the Merco Centrifugal Company, in which the attempt was made to separate the first carbonation mud by the use of the solid bowl continuous centrifugal.

It was found that the centrifugal would indeed separate the mud, and it made no difference in its separation whether the alkalinity of first carbonation was 0.060 or 0.130, or even whether or not there was recirculation in first carbonation.

Apparently the centrifugal exerted a powerful shearing force on the mud, which was not found in the batch type solid bowl centrifugal, and which broke up the agglomerates of calcium carbonate crystals. There was no difficulty in obtaining a high density underflow from the centrifugal, but it could not be filtered on rotary vacuum filters because the agglomerates had been broken up and the small pieces sealed the filter cloth. The centrifugals were relatively expensive, and the project was abandoned.

## Conclusion

In conclusion we wish to restate that the purpose of this paper was to review work done to determine the optimum settings for the various variables in Dorr system continuous first carbonation. While other systems of carbonation may be superior in certain respects, we have never found one which, as a whole, would be more economically advantageous for us.

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# The Chemistry of Lime Salts in Sugar Beet Juices

J. Dedek

The chemistry of lime salts in sugar beet juices presents, both from the practical and the theoretical point of view, many features of great interest.

We see in practice a complete range, starting from juices with practically no lime salts at all—giving no precipitate with ammonium oxalate solution—up to juices with several tenth of a p.c. of CaO. We see sugar industries—like the Swedish one—very careful about the slightest increase in lime salts—and on the other side—e.g. the Irish one—processing without great troubles juices extremely high in lime salts—with complete indifference to them.

If we try to formulate the more important practical experiences, concerning the behavior of lime salts, we can list them in the following order:

1. In second-carbonation juices there exists lime salts and (carbonate?) alkalinities simultaneously in concentrations far exceeding those ever found in water solutions. This fundamental fact has been formulated in a very clear way for the first time—as far as I know—by two Czech chemists, V. Sykora and J. Schiller in 1881.

2. The amount of lime salts is not inversely proportional to the alkalinities of juices. Sometimes even strongly alkaline juices contain great amounts of lime salts.

3. A high second-carbonation temperature sometimes increases, sometimes decreases the amount of lime salts

4. The same contradictory observations have been made when boiling out unfiltered second-carbonation juices.

5. The addition of soda ash does not precipitate the equivalent amount of lime salts. The efficiency of precipitation varies very considerably from juice to juice.

6. Soda ash—though decreasing the lime salts in second-carbonation juice—increases sometimes the rapidity of scaling in the evaporators—so that many practical sugar men prefer to process juices high in lime salts—rather than using soda ash.

7. The amount of scaling is not proportional to the amount of lime salts in second-carbonation juices. It seems that not all lime salt is "harmful."

8. Evaporation thick juice does not always yield incrustations—though it ought to be a very strongly supersaturated solution of (at least) $CaCO_3$.

9. The alkalinity (pH) of the thick juice is sometimes higher, sometimes lower than the alkalinity (pH) of the corresponding second-carbonation juice.

10. The formation of scales has been observed even before the evaporation, i.e., in the filter clothes of second-carbonation filters etc., though the optimal second-carbonation alkalinities have been maintained correctly.

11. Scales formed, say in the first part of the campaign, have been seen redissolving again in the further course of the processing season, and this even with juices very rich in lime salts.

It is rather interesting to see how these contradictory, seemingly unrelated facts can be made to fit beautifully in one single and coherent picture of the behavior of lime salts—if we try to understand them, in other words to formulate them in a somewhat theoretical way.

This theory is a very primitive one.

A. We are eliminating the $Ca^{++}$ from our juices in the form of $CaCO_3$, which leads to the fundamental equation

$$(Ca^{++}) \cdot (CO_3^{=}) = K_{CaCO_3}$$

The product of the concentrations of the $Ca^{++}$ and the $CO_3^{=}$ in a certain saturated $CaCO_3$ solution has a constant value, called the solubility product of $CaCO_3$.

Let us see what this simple equation can teach us.

In figure 1 are reproduced two solubility (ionic) products $(Ca^{++})$ and $(CO_3^{=})$, one of which has the value $K=1$, the other one $K=16$. It is now important to remember that when we know the composition (eg) $(Ca^{++})$ and $CO_3^{=}$) of one sample of a—say second-carbonation juice—we are able to trace the whole corresponding curve, for which $(Ca^{++})$ $(CO_3^{=})$ has the same value.

These curves allow us to follow the deliming effect of an addition of soda ash. Say our juice has the composition of point 1 at curve $K=1$ and we add an amount of soda ash equivalent to 1 part of $CO_3^{=}$ A simple geometric construction allows us to find point 2 giving the composition of juice 1 after soda-ash treatment. The vertical line in 2 gives the deliming which is very marked in this case. Other similar cases are marked by points 3, 4 and 5, 6.

We see clearly that—in order that K remains constant—one part of the soda ash added must be utilized to increase the $CO_3^{=}$ concentration and thus cannot react with the $Ca^{++}$—in other words the soda ash can never precipitate equivalent amounts of $Ca^{++}$.

The comparison of point 1 and 3 tells us that—all other conditions equal—the less lime salts a juice contains, the less effective is a certain addition of soda ash—and the comparison of points 1 and 5 shows that in different second-carbonation juices having the same concentration of lime salts $(Ca^{++})$, the deliming effect of a certain amount of soda ash is the smaller, the greater the $K_{CaCO_3}$ of such juice.

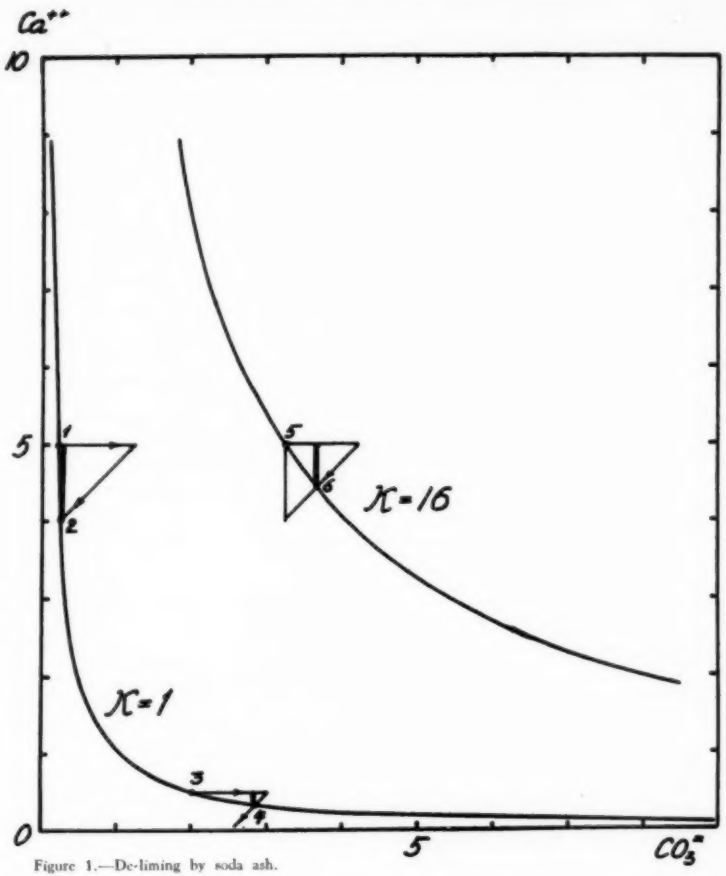



Figure 1.—De-liming by soda ash.

Thus the effect of soda ash depends on the position of the corresponding juice on its K-curve, 1 as against 3, and on the absolute value of K, 1 against 5. This gives a satisfactory explanation of No. 5 of our list.

But the decrease of $Ca^{++}$, due to soda ash, must not necessarily mean also a decrease in the amount of $CaCO_3$, which could eventually form deposits. This is emphasized in figure 2. Juice 1 has twice as much lime salts as juice 2—the latter having been treated by soda ash. But the total amount of $CaCO_3$ which could crystallize out as such is given not by the content of $Ca^{++}$ but by the much smaller amount of $CO_3^{=}$ which is so to say the "limiting factor" in these two juices. This amount can be read at the $CO_3^{=}$ axis and is marked by the end points of the vertical lines drawn from 1 and 2.

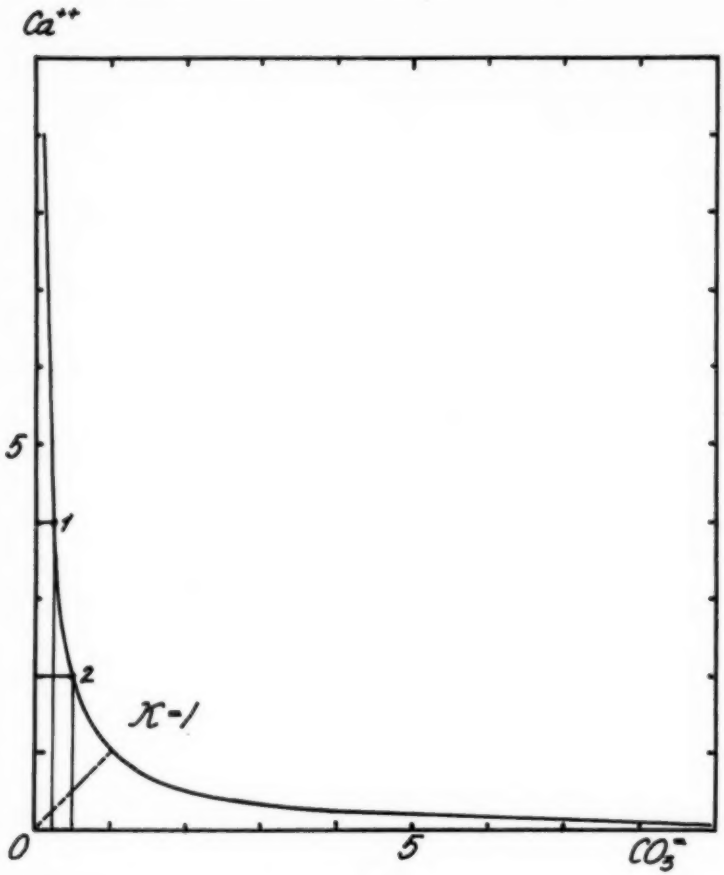



Figure 2.—"Paradox" of the soda ash treatment.

We see clearly that, by decreasing—by soda ash—the $Ca^{++}$ of juice 1 to one half in juice 2 we have at the same time doubled the amount of $CO_3^{=}$ in other words doubled the quantities of $CaCO_3$ in solution—and thus also increased the danger of scaling by $CaCO_3$. We called this rather unexpected effect the "paradox" of soda-ash treatment and it gives us a good explanation of No. 6 of our list of puzzling facts.

Both our curves give us also a simplified picture of the possible changes due to the evaporation of second-carbonation juices to thick juices (figure 3). If we abstract of all—the very many complications which actually take

place—we can consider what happens if the volume of second-carbonation juice is decreased to ¼ in the evaporation. In such case both $Ca^{++}$ and $CO_3^{=}$ increase 4 times and their product becomes K=16.

If we suppose further—in the first approximation—that the solubility of $CaCO_3$ in thick juice is the same as in the original thin juice (K thick juice=1), part of the $CaCO_3$ must crystallize out.

It is practical to subdivide the process in two steps—considering first the formation of a very supersaturated solution with K=16 and then the crystallization of $CaCO_3$.

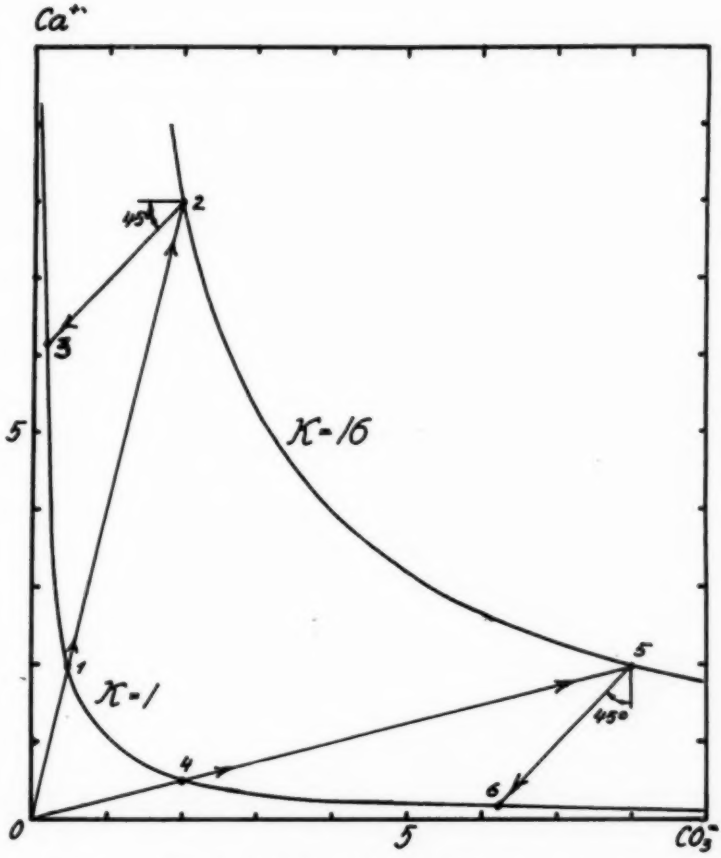



Figure 3.—Change in $CO_3^{=}$ and $Ca^{++}$ in the evaporation.

Figure 3 gives us both curves K=1 and K=16. We shall start evaporating the second-carbonation juice marked by the point 1. Its composition changes along the line 0-1-2, where $Ca^{++}$ and $CO_3^{=}$ increase in the same proportion. The point 2 marks the composition of the strongly supersaturated thick juice (K=16).

If in the second phase of the process, $CaCO_3$ starts crystallizing, equivlent amounts of $Ca^{++}$ and $CO_3^{=}$ disappear from the solution as solid $CaCO_3$ and the composition of the juice changes along the line 2-3, the point of intersection with curve K=1, representing the composition of the thick juice, just only saturated with $CaCO_3$.

Points 4, 5, 6 are telling the same story of the second-carbonation juice of composition 4.

It is now very interesting to see first of all what happens with the alkalinity between thin and thick juice. We see that it has slightly decreased in the case of juice 1 and very markedly increased in juice 4. (A corresponding opposite change took place in the—volume—concentration of $Ca^{++}$.) This solves the mystery of contradiction No. 9 of our above list.

The difference in the $Ca^{++}$ of 2 and 3, or 5 and 6 gives the amount of $Ca^{++}$ crystallized out in the form of $CaCO_3$. These differences plotted against the $CO_3^{=}$ contents of the corresponding original thin juices give curve △ in figure 4. We see again the "paradox" of the decreasing danger of ($CaCO_3$) scale formation, as the content of lime salts in the thin juice increases—the most dangerous juice being the one having $(CO_3^{=}) = (Ca^{++})$.

There is still one point of great interest and practical importance, which can be easily guessed from figure 3 or 4, namely the influence of a decrease in $CO_3^{=}$. We see clearly that a slight loss in $CO_3^{=}$ during evaporation of juice 1 would shift 2 along a line, parallel to the $CO_3^{=}$ axis and at the same time lift 3 along the curve K=1—up to a moment, when 2 and 3 would coincide in the K=1 curve. In such a case there would be no $CaCO_3$ in over-saturated solution and the thick juice would be a saturated solution of calcium carbonate. A further loss in $CO_3^{=}$ would give a thick juice undersaturated in $CaCO_3$ and thus capable of even dissolving $CaCO_3$ scales already formed! We see further that the absolute loss of $CO_3^{=}$ necessary is the smaller, the greater the amount of $Ca^{++}$ in the thin juice. This explains No. 11 of our list.

B. The above mentioned possibility of a change in the $CO_3^{=}$ concentration brings us to the second theoretical point we must discuss. It is the dissociation of carbonic acid. We all know that it dissociates in two steps

$$H_2CO_3 > H^+ + HCO_3 \text{ and}$$
$$HCO_3 < H^+ + CO_3^{=}$$

with $pK_1 = 6.36$ and $pK_2 = 10.25$ at 25° C. A graphical extrapolation of the values for different temperatures gives approximately 6 and 10 for 85° C. (figure 5). We all know that—but we somehow forget all about it when discussing second-carbonation. We especially forget the tremendous importance of the pH on the degree of ionization—that is on the per-

centage of the total carbonic acid present, which exists in the $CO_3^=$ form —and which is the only one taking part in our fundamental equation $(Ca^{++})\ (CO_3^=)=K_{CaCO_3}$.

A simple calculation shows, however, that between pH 8 and 9 the percentage $CO_3^=$ increases from 0.6 to 5.6 percent. A further rise of the pH to 10 increases the percentage $CO_3^=$ to 37 percent. Now the extreme pH of normal, healthy and correctly carbonated second-carbonation juices of my country are, according to our experiences 8.2 and 9.4, which (at 25° C) correspond to from 1 to 13 percent $CO_3^=$.

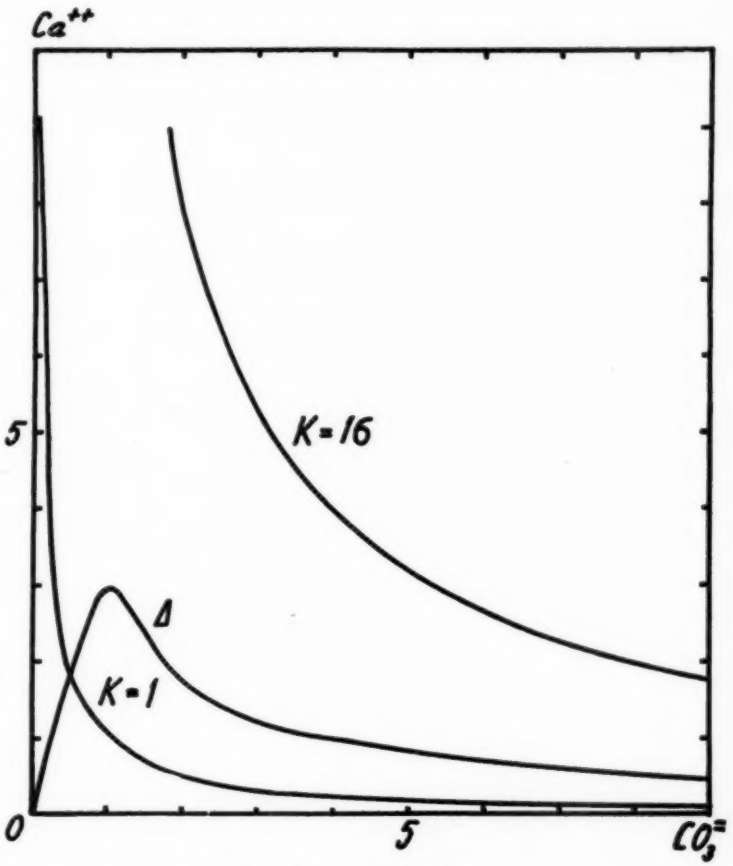



Figure 4.—Amount of $CaCO_3$ (△) in supersaturated solution.

It is not without interest to compare these values with the total amount of carbonic acid present in the same juices. In our own determinations we found (expressed as CaO p. 100 ml) values between 5.2 and 70.3 mg. Now, if such quantities of carbonic acid were present in the form of $Na_2CO_3$ in pure water solutions, the corresponding pH can be easily calculated and would be from 10.6 to 11.2—thus far higher than those of our thin juices. In the water solution up to 90 percent of all the carbonic acid present exists in the $CO_3^=$ form, as compared with 13 percent in the juices! What is the reason of these low values in juices?

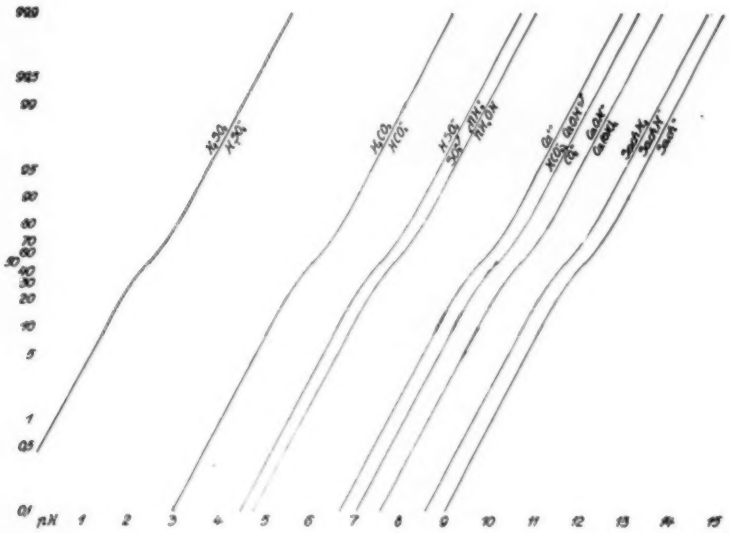



Figure 5.—Ionization curves.

Here, the $Na_2CO_3$ or $K_2CO_3$ is not dissolved in pure water but in a solution of an acid—the sucrose, whose $pK_1$ of 12.6 at 25° C. is sufficiently close to the $pK_2$ of carbonic acid, to be able to depress considerably its dissociation—and thus render it still more difficult to "delime" our juices.

From the figure 6, reproduced from the very interesting article of the young Danish chemist H. Brueniche-Olsen (SUGAR, October 1947), follows, that in a sugar solution at 85° C. in the maximum about 25 percent $CO_3^=$ exist at a pH of 9.5. His pH values have been of course measured by the aid of a tungsten electrode.

In any case, this influence of sucrose on the ionization of carbonic acid explains away the puzzle No. 1—the coexistence of large quantities of lime salts and "carbonate" alkalinities in beet juices.

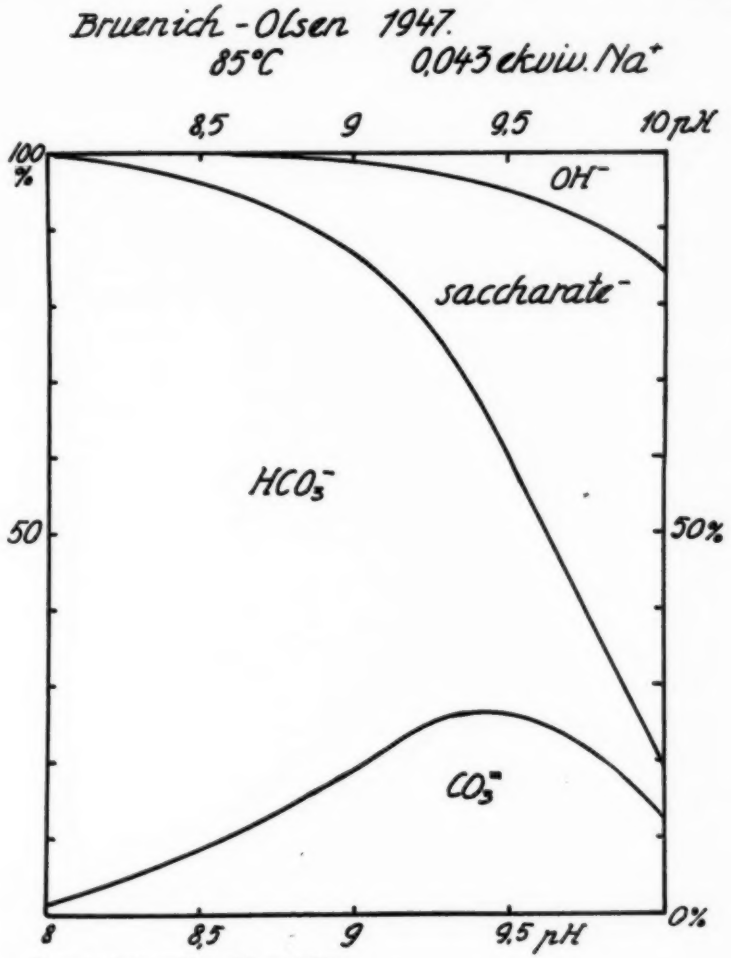



Figure 6.—Ionic equilibria of Bruenich-Olsen.

C. It is time to consider now the ionization of the $Ca(OH)_2$. This is a divalent base and the literature is giving its $pK_1=11.6$ and $pK_2=12.5$ at 25° C.—which by a rather uncertain extrapolation gives 9.7 and 10.6 at 80° C.

We see that $Ca(OH)_2$ is a very weak base, whose pK overlap those of carbonic acid and sucrose (figure 5). This is the reason why there is little possibility for milk of lime to react in solution with sucrose—as can be

seen from figure 1, giving the ionization curves in Michaelis' form (percentage ionization) of the different ions which $Ca(OH)_2$ resp. sucrose (considered as a divalent acid, $pK_1=12.6$, $pK_2=13.1$) can form. In order to ionize sucrose—we need big pH-es, at which however the ionization of $Ca(OH)_2$ is but very low—and vice versa. The different intersection points (a, b, s, d) show the maximum amounts of the different cations ($CaOH^+$, $Ca^{++}$) and anions (Sach H—, Sach=) which can co-exist. The highest value (c) is only about 21 percent—all the rest being "hydrolyzed." This is the explanation of one of the difficulties of a Steffen method—and also of the advantages of the barium process—where we utilize the much stronger base $Ba(OH)_2$ with a $pK_1$ of 13.28, which is 1.6 higher than the $pK_1$ of $Ca(OH)_2$.

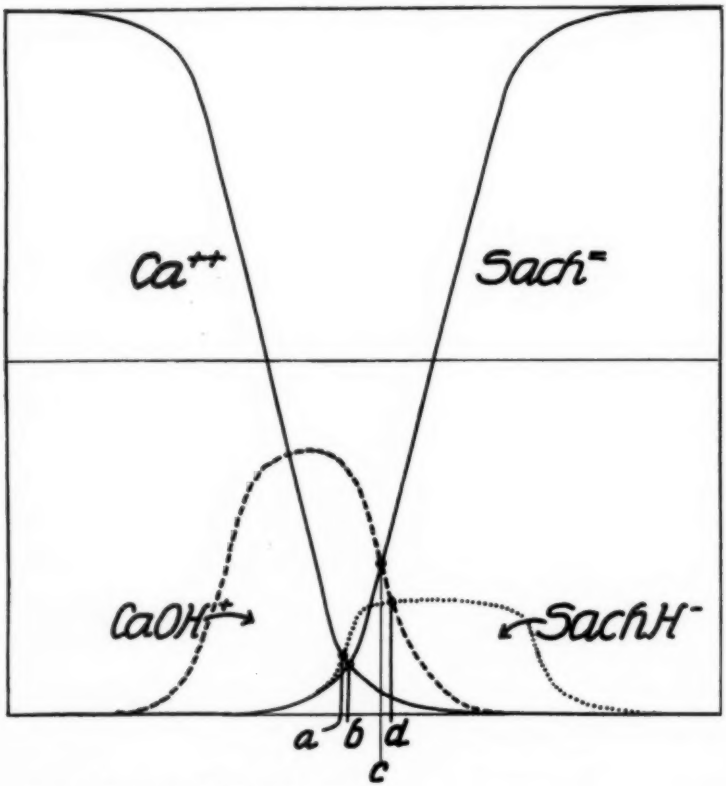
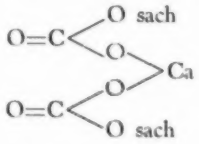



Figure 7.—Reactions of $Ca(OH)_2$ with sucrose.

The possible reactions of carbonic acid ($Co_3^=$ and $HCO_3^-$) with milk of lime ($CaOH^+$, and $Ca^{++}$) can be guessed in a similar way from figure 8. We see that about 42 percent of $CaCO_3$ can exist in solution unhydrolyzed—and nearly 98 percent of $Ca(HCO_3)_2$, $H_2CO_3$ being a stronger acid than $HCO_3^-$.

The reactions are still more complicated when considering all the three components, namely, carbonic acid, sucrose and milk of lime simultaneously—say in neutralizing a $Ca(OH)_2$—sucrose solution with carbonic acid. The school of Bjerrum and Faurholt have been able to show that in such a case—at least at lower temperatures—the primary products are alkylcarbonates possibly of the type




which in a secondary, rather slow reaction decompose into free sucrose and $CaCO_3$.

This is one of the reasons why limpid sugar-lime solutions can be treated with $CO_2$ at low temperatures without giving the slightest precipitate; we were able to keep them for hours, absolutely brilliant and limpid.

D. The conditions are getting still more complex if we take in consideration the presence of other substances (ions) than sucrose, carbonic acid and lime.

As we are mostly interested in lime salts—let us start with the anions, which must necessarily accompany any $Ca^{++}$ of lime salts.

It is very interesting that already 20 years ago, in 1928, a Dutchman, van der Heide, in a very important paper (published in Chemisch Weekblad), which however remained completely unobserved, was able to show the importance of the pK of the acids forming lime salts. Figure 9 reproduces a part of his curves. We see clearly that the weaker the acids (the higher their pK) the smaller amount of $Ca^{++}$ remains in solution and the higher the corresponding "optimal" pH of the second carbonation.

We can resume, in a crude way, the results of van der Heide in saying, that carbonic acid partly liberates the "free acids," forming the lime salts. These depress the pH the more, the stronger the acid present.

We become thus aware that it is not allowed to consider only our fundamental equation $(Ca^{++})\ (CO_3^=)=K_{CaCO_3}$—but as we have already learned from the influence of the sucrose on the ionization of carbonic-acid—that we must respect the interplay of all the ions present in the juices.

The second non-sugars which we can take in consideration are the aminoacids (and ammonia).

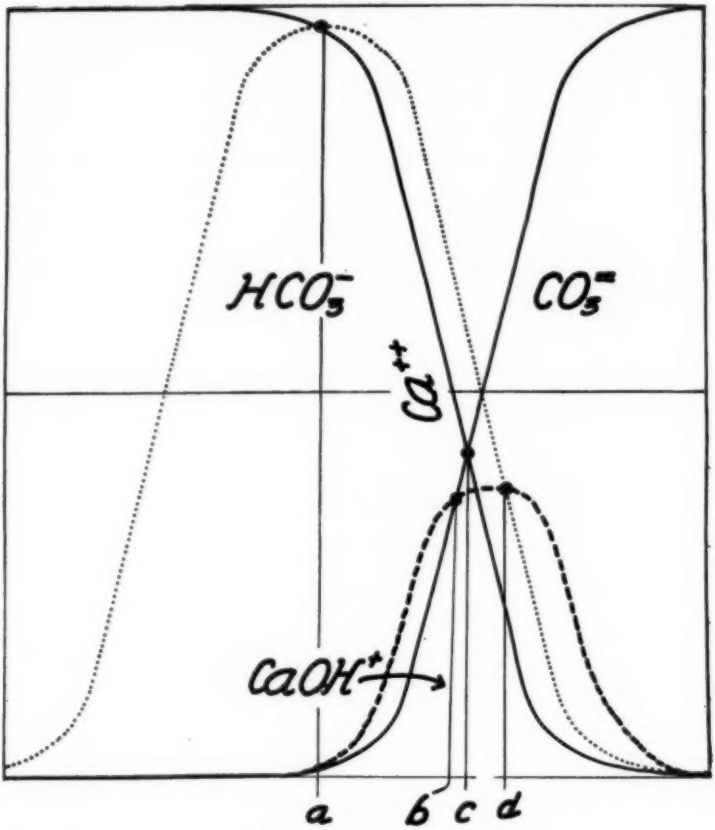



Figure 8.—Reactions of $Ca(OH)_2$ with $H_2CO_3$.

Faurholt has extensively studied the reactions, velocities and equilibria between carbonic acid and ammonia resp. aminoacids in forming carbaminates of the type

$$O=C<\begin{matrix}NHR\\OH\end{matrix}$$

The papers of Faurholt present a fascinating subject which however is mostly outside our present aim. But we must point out that this type of reaction can account for a part of the "non carbonate" $CO_2$ bound in the juices (see also the papers of Majer).

We are indebted to Siegfried for a thorough study of the solubilities of the Ca-carbaminates of amino acids. It is still an unsettled question whether these badly soluble salts can be present in the juices under condi-

tions of our carbonations and can account for any $NH_2$—nitrogen being eliminated in the usual juice purification—or increase the amount of lime salts of our second-carbonation juices.

There is a certain evidence that protein substances, or their destruction products, if not properly eliminated are able to increase the solubility of $CaCO_3$—either by some form of the Siegfried reaction—or by diminishing the activity of $CaCO_3$.

Figure 10 shows the possible interreactions of $Ca(OH)_2$ with the manifold ionized forms of a protein (the curves correspond to egg-albumin, whose dissociation constants have been determined by Ettisch and Schulze).

We can easily imagine how complicated the diagram would become if we were to include the curves for sucrose, carbonic acid and the different possible carbamiacids!

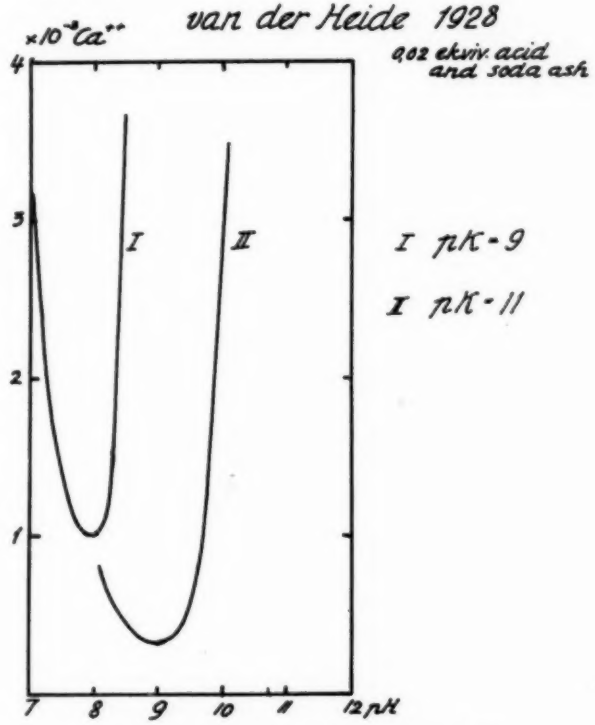



Figure 9.—Influence of the strength of acids forming lime salts on deliming.

E. We have just mentioned activities. In reality—even our fundamental equation

$$(Ca^{++})\ (CO_3^{=}) = K_{CaCO_3}$$

deals exclusively with activities and not concentratons. Thus, not the total amount of—say—lime, determined by soap solution in our juices, but only the active concentration of the $Ca^{++}$, the pCa, takes part in the above equation.

The activity of the calcium ion is extremely important in the human physiology, but—up to the present time—no rapid and sufficiently precise method for the determination of pCa has been found. We are still very far away from anything which would resemble even an old fashioned hydrogen electrode for the determination of pH—not to talk of the splendid glass electrodes.

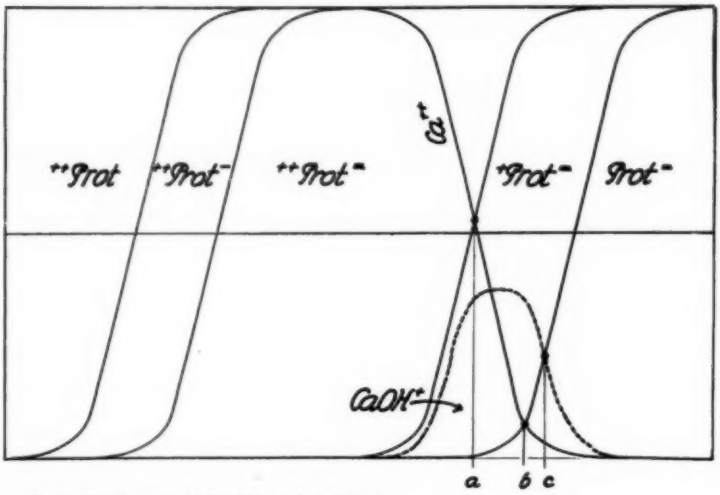



Figure 10.—Reactions of $Ca(OH)_2$ with avalbumin.

But even the results arrived with the aid of the crude methods used at present enable us to draw some very important conclusions regarding our problem of lime salts.

The Danish chemist Kilde, working in the laboratory of Bjerrum, was able to show that in a 17 percent sugar solution, containing 0.3 to 0.5 percent CaO, only about 2 to 8 percent of the total amount of lime exists as $Ca^{++}$.

The British electrochemist Davies proved that lime salts of alfa-OH or alfa-$NH_2$ acids give off only some few (2-4) percent $Ca^{++}$. The effect of citric acid on the ionization of Ca is well known.

Both Davies and Kilde have independently been able to prove the existence of complex Ca-ions of the general formula $(Ca\ An)^+$.

Chelated Ca salts of alfa-$NH_2$ acids discovered by Davies, would be another form of undissociated lime salts—all of which of course merely increase the total amount of Ca in our juices—without taking part in the fundamental equation of the solubility product of $CaCO_3$.

How important and manifold are even reactions between $Ca^{++}$ and proteins can be guessed by the recent monography of 28 pages by David M. Greenberg of the University of California Medical School.

Two of my collaborators, F. Cuta and M. Sevela, using Harnapp's electrode, tried to determine—for the first time in the beet sugar industry—the pCa of sugar beet juices—and found, from thin juices to molasses, values ranging from $pCa=10^{-4}$ to $10^{-9}$—thus extremely low values, though these products contained several tenths of milligrams CaO/100 ml.

This again helps to explain the puzzle No. 1 of our above list—but itself creates a new problem—how to explain this low pCa and how to understand it.

F. But in processing our juices—and creating lime salts—we do neither use calcium ions nor carbonate ions. From the gaseous $CO_2$ of our carbonation gases there is a very long and complicated way to the $CO_3^=$ we have been talking about. In order to see the complexity of the problem, it is however necessary to point out, that $CO_2$ first has to be absorbed and dissolved as a gas. Then it is hydrated to $H_2CO_3$—by reactions studied i.e. by Faurholf, 1924, in a paper of 70 pages. Vasátko and myself have just only touched the problem of the influence of sucrose and non-sugars on the velocity of $CO_2$ hydration. The whole field is still full of open problems.

We find the same state with CaO, which Kohlschütter considers to be a solid colloid, dissolving to a marked degree as a colloid, so that van Aken and later Kmunícek could ultrafilter limpid CaO-sucrose solutions through membranes. There is yet nothing known about the importance of the degree of dispersity of CaO on the effect of the juice purification, the formation of lime salts, etc., etc.

G. We have already mentioned the changes taking place during the evaporation. Figure 5 shows how great are the amounts of $H_2CO_3$ (and consequently of $CO_2$) in juices of normal pH. It is, therefore, quite natural that part of this $CO_2$ escapes with the vapours, thus decreasing the total amount of carbonic acid (which tends to decrease the $CO_3^=$)—but at the same time increasing the pH (which tends to increase the $CO_3^=$). This only adds to the complexity of the conditions.

H. Still more potent and difficult to master are the various destructive reactions (of sucrose, reducing sugars, amides, ammonium, etc.) which take place before, during and after the juice purification and give all raise to acid products—decreasing the pH and, or, increasing the amount of lime salts present.

I. But—when deliming our juices with carbonic acid—we must filter off the precipitated $CaCO_3$. Or—there is again a long and painful way to go, e.g., the formation of a new phase with all its difficulties—we know so well from our boiling pans, where we produce a solid phase of sucrose. There are many indications that $CaCO_3$ forms very easily supersaturated solutions in second-carbonation juices and Brueniche-Olsen stresses this point again very emphatically in his above mentioned paper. This explains point 10 of our list.

The above is but a selection of the more important problems connected with lime salts in sugar beet juices. Many more could be discussed. Sufficient, however, has been said to make it clear, that the true meaning of this paper is not so much to give information about the chemistry of lime salts in beet juices, but to show the importance of theory and of fundamental research in the sugar beet industry. The writer would be satisfied if the above rudimentary applications of a very elementary electro-chemistry would show how theory can deepen our understanding—and, therefore, our mastering of technical processes—as nothing is more practical than a good theory.

# A Continuous, Automatic Device for Alkalinity Measurement and Control

E. E. Morse[1]

While there is certainly not universal agreement among sugar processors on the point, it is the belief of the Spreckels Sugar Company that the most important controlling variable in the first-carbonation process is the alkalinity of the filtered juice. This belief is based on several years' work with a bench-scale carbonation apparatus, some of the results of which have been published (1).[2]

If it is agreed that the alkalinity offers the best method of carbonation control, then the usefulness of an apparatus which will automatically and continuously measure the alkalinity is apparent. If this apparatus can also control the carbonation process, its value will be further enhanced. We have developed such an automatic device and have used it for several years at the carbonation station in our Woodland factory.

## General Method of Operation of the Alkalimeter

The determination of alkalinity is simply a titration of an alkaline solution with an acid solution. The filtered first-carbonation juice is the alkaline solution and 0.0357 normal sulfuric acid is the acid solution. The strength of the acid is so chosen that when a 10-milliliter sample of the filtered juice is taken, the volume of acid required for neutralization divided by 100 is the numerical measure of the alkalinity. Furthermore, the alkalinity equals the number of grams of calcium oxide per 100 milliliters of juice, assuming that calcium hydroxide is the only alkali present in the juice.

First-carbonation control depends primarily upon the determination of the alkalinity which is made manually by the carbonation operator. Thus, the operator takes a sample of first-carbonation juice from the carbonation tanks, filters the juice and titrates a 10-milliliter sample of the filtrate with 0.0357 normal sulfuric acid, using phenolphthalein as a color indicator. If the measured alkalinity of the juice varies from the desired figure, the addition of milk of lime or carbon dioxide gas is changed so as to obtain the desired figure.

Approximate alkalinity control is frequently obtained by the use of intermediary devices such as pH or conductivity controllers. The principal objection to these devices is that other factors such as temperature or percentage of lime may alter the relationship between alkalinity and pH or alkalinity and conductivity.

Inasmuch as the determination of alkalinity is simply an acid-base titration, it is clear that an alkalimeter must automatically perform this

[1]Research Chemist, Spreckels Sugar Company, Woodland, California.
[2]The numbers in parentheses refer to literature cited.

titration, plus the added step of preparing the first carbonation juice for titration. First, the juice must be filtered and cooled and delivered to a mixing chamber at a uniform rate. Inasmuch as the alkalinity will vary while the flow is constant, the number of equivalents of base delivered per minute will vary.

The dilute sulfuric acid will incompletely, exactly or more than completely neutralize the base present in the filtered Dorr feed, depending on the flow and the concentration of the acid. As it is not practical to vary the concentration of the acid, the state of neutrality must be reached by varying the flow. Thus, a unit is needed to detect the acid-base unbalance and actuate a device which will vary the flow of acid. This flow-controller must also incorporate a flow indicator, which of course is also an alkalinity indicator. And, if possible, the alkalinity indicator should be capable of exercising control over factory carbonation so that it may be carried out at any desired point.

Fortunately, the acid-base unbalance can be detected by any of various pH measuring devices. These devices can in turn be made to operate electrical and mechanical equipment to vary the flow of acid either directly by operating a valve or changing the static head involved or indirectly by any of more or less complex devices.

The whole problem of development, then, resolves itself into finding that combination of pieces of apparatus which will best carry out this automatic titration.

## Nature of the Alkalinity Titration Curve

Automatic control of the acid-juice titration depends to a large extent on the nature of the titration curve. Figure 1 shows the results obtained in titrating four samples of filtered first-carbonation juice with factory acid, using glass and calomel electrodes to measure the pH at 25° C. The third curve was obtained by titrating a dilute solution of sodium hydroxide which contained some sodium carbonate. Nitric acid gives practically identical curves. It is evident that the solutions are quite strongly buffered. The true neutrality point in an acid-base titration is taken as the point of greatest slope in the titration curve. It was found that the pH end-point was the same in solutions ranging from 0.060 to 0.155 in alkalinity, namely 7.08 $\pm$ .06 for the four runs. In the case of curve three, two additional inflec tional points were noted at the bicarbonate and carbonic acid end-points.

Due to the fact that the curves are not precipitous in the immediate vicinity of the end-point, the use of phenolphthalein introduces an error in the determination of alkalinity. It was found by measurement of the neutralized solution with a glass electrode that the pH of juice titrated using phenolphthalein as an indicator was about 7.9. This titration was carried out in the manner in common use at Woodland, using a considerable excess of the indicator. Such a method reduces the error due to the natural coloring matter of the juice. From the curves in figure 1, it is seen that the measured alkalinity when using phenolphthalein is about 0.0035 too low. If the alka-

linity is to be correct within ± 0.0025, the pH at the end-point must be held within about ± 0.7. It should be noted that this refers to the juice titration and not to first-carbonation control where the alkalinity-pH coefficient is much greater.

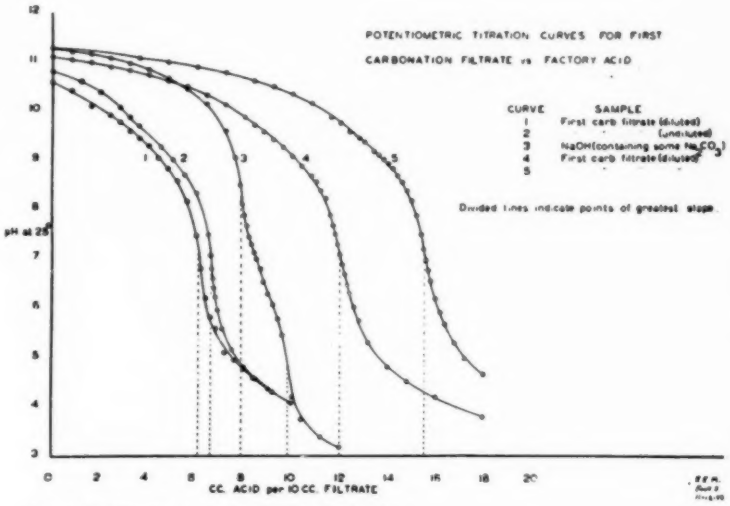

POTENTIOMETRIC TITRATION CURVES FOR FIRST CARBONATION FILTRATE vs FACTORY ACID
CURVE SAMPLE
1 First carb filtrate (diluted)
2 (undiluted)
3 NaOH (containing some $Na_2CO_3$)
4 First carb filtrate (diluted)
5
Divided lines indicate points of greatest slope.
pH at 25°
CC. ACID per 10 CC. FILTRATE

Figure 1.—Titration curves for first-carbonation juice.

## General Description of Apparatus and Method of Operation

Figure 2 is a schematic diagram of the alkalimeter to which reference may be made in following the description of its operation.

The juice sample is taken from the recirculation line of the first-carbonation tanks, on the pressure side of the recirculation pump. It flows into a filtration pot in which are placed two Oliver-Borden type filters, which are connected through a reciprocating valve to sources of air pressure and vacuum. Sixteen-ounce duck cloth is used as the filtering medium and the filter cycle is set at 3 inches of vacuum for 17 seconds and 1 pound per square inch pressure for 7 seconds. For a more nearly continuous supply of juice, it is best to use two filters. Each filter must be connected to a separate filtrate receiver, but both receivers discharge through check valves into the same supply tank.

The filtered juice is next cooled and run into a miniature constant level tank from which it flows through a tube and out a glass capillary tip. The capillary tip is used so that a reasonably high static head may be employed and yet the flow rate will be a reasonably small value. This permits accurate adjustment of the constant juice flow.

The flow of filtered juice is easily controlled inasmuch as it is constant. The requirements for constant flow are (a) constant static head, (b) constant temperature, (c) constant orifice diameter and (d) constant composition of juice. Requirement (a) is easily satisfied and the heat exchanger in the filter system maintains the juice temperature within a few degrees. The juice composition should not vary sufficiently to affect the flow appreciably. The variation in factor (c) is not as easily estimated because scaling might cause a reduction in the orifice diameter. Tests to date have shown that this scaling effect is negligible over a period of 1 or 2 days. It may become serious, however, in a longer run, but an acid rinse will quickly dissolve the scale.

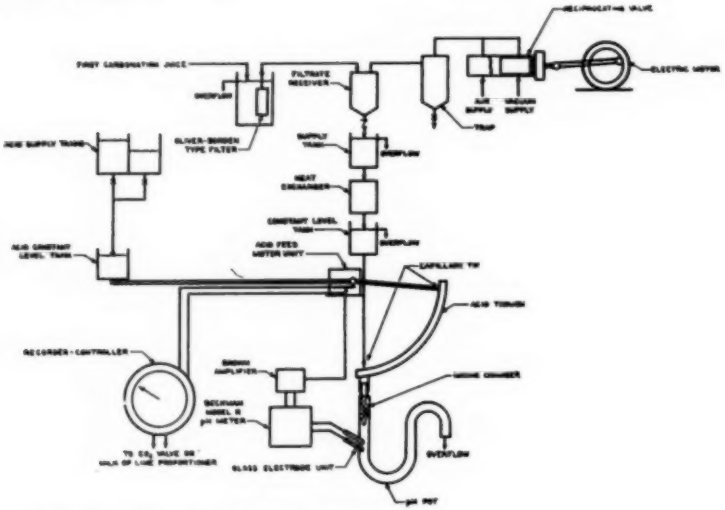



Figure 2.—Schematic diagram of the alkalimeter.

The acid is stored in two large stainless steel tanks, one of which is in use while fresh acid is prepared in the other. From the storage tank the acid flows to a constant level tank, in which the level is controlled by a glass float valve. From this tank the acid flows through another tube and out a glass capillary tip. In this case the static head is variable, as will be explained later. Provisions are included to thermostat the acid.

The acid and juice are mixed intimately and passed by or through a detecting element which determines whether equivalent amounts of acid and alkali are present. This detecting element may be an optical system composed of a light source, color filters and a photo-electric cell. In such a case an indicator must be mixed with the acid. It may also be a set of electrodes to measure the electrical conductivity of the solution. Any of a number of different galvanic cells may be used to measure the hydrogen ion

activity in the solution. Examples of these cells are the antimony-calomel cells and the glass electrode-calomel cells. Inasmuch as the hydrogen ion activity is the most direct and exact measure of the degree of neutralization, we use a galvanic cell composed of a glass electrode and a saturated calomel electrode as the detecting element. Within 5 seconds after a change in the flow of acid, there should be an indicated change in the pH of the mixture in the pH pot.

The pH electrodes are connected to a Beckman Model R pH meter which is so adjusted that no current actuates the indicating milliammeter when equivalent amounts of acid and base are flowing through the pH pot. This has been shown to be the case when the pH is 7.08 at 25° C.

Now let us suppose that the alkalinity of the juice increases slightly. Since the flow rate of the juice is constant, the number of equivalents of alkali flowing per minute increases. This causes the pH of the acid-juice mixture to rise and current flows through the Beckman instrument milliammeter. Similarly, if the juice alkalinity decreases, the pH falls and current flows through the milliammeter in the opposite direction, i.e., the needle drops below the zero mark.

The change in pH must be made to cause a change in the flow of acid so as to restore the pH to 7.08. This is done by amplifying the small unbalance current from the pH meter with a Brown Instrument Company amplifier which in turn drives a reversible split phase motor. This motor is mounted in a Leeds and Northrup motor drive unit which also incorporates a gear train, output shaft and limit switches. The tube through which the acid flows is attached to the output shaft so that the capillary discharge tip can be moved in either a clockwise or counter-clockwise direction so as to dispense the acid into a circularly shaped trough. If the pH is above the control valve, the reversible motor will operate so as to rotate the acid dispensing tube in a clockwise direction and increase the flow of acid. As the pH approaches 7.08, the rate of rotation of the dispensing tube decreases and stops at the control point. The advantage of the Brown amplifier unit over a more conventional relay system is that the rate of operation is high when far away from the control point and becomes progressively slower as the control point is neared. This is highly desirable from a control standpoint. It is apparent that the acid dispensing tube will always move so as to restore the chemical balance in the mixture of juice and acid.

For any given juice alkalinity, there will be one and only one position of the acid dispensing tube which will produce a chemically neutral mixture. Hence the position of the tube is a measure of the alkalinity. The tube position may be indicated and recorded readily by connecting a resistance measuring instrument to the variable resistance which is an integral part of the Leeds and Northrup motor unit.

The alkalinity recorder must be calibrated under the conditions which will be used in actual operation. We use 75.0 milliliters of first-carbonation juice per minute and the strength of the nitric acid is 0.0250 normal

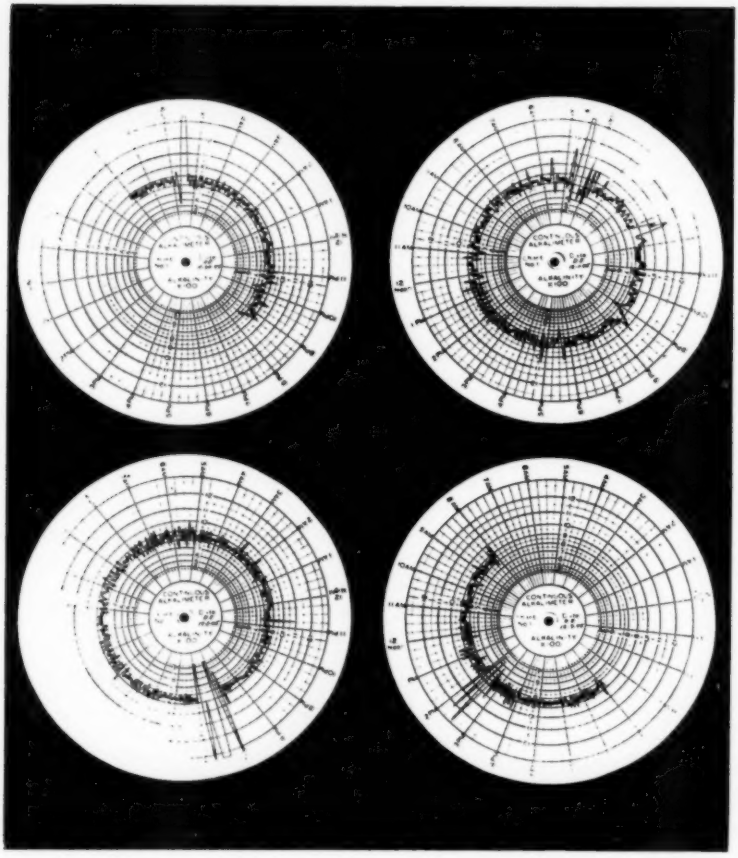


Figure 3.—Sample records of first-carbonation alkalinity control.

It is readily possible to use a recorder-controller in place of just an alkalinity recorder. In the installation at Woodland, the controller is used to position the kiln gas valve. In cases where control is effected by changing the milk of lime or saccharate milk flow, the alkalinity controller may be used for that.

## Comparison of Alkalinity Determined by Alkalimeter and by Manual Titration

Many measurements have been made on various samples of juice to check the accuracy of the alkalinity as determined by the automatic titrator. Rather than include a lengthy table, only average values will be given. For

67 measurements, the average alkalinity determined by the alkalimeter was 0.0841 and that determined on 67 samples of juice titrated by hand was 0.0807. The average difference of 0.0034 is due to the fact that the pH end-point used in the phenolphthalein titration is not the true end-point, as was pointed out previously. The difference which one would expect from the titration curves (figure 1) is 0.0035. It is to be noted that the alkalimeter can be adjusted to titrate to any desired pH end-point.

## Automatic Control of Alkalinity

As an illustration of the sort of control which has been obtained with the alkalimeter, we refer to figure 3, which shows the charts obtained in a 72-hour run during which rather complete data were taken on most of the variables affecting the process. The average alkalinity was 0.0856, which is quite close to the control value of 0.0850. At four different times, control was apparently lost; however, it was shown that these upsets were due to beet-end operating difficulties such as a plugged saccharate milk line to the carbonation station. At another time, the carbonation operator increased the saccharate milk flow by a large amount and considerable deviation occurred before control was again established.

The persistent cycling which was noted at times was due to an insufficiently wide throttling range. Little could be done about this point, however, as the control instrument was set at its lowest sensitivity.

## Conclusion

An automatic alkalimeter can be used solely as a recording instrument and is of most value in such an application as a means of determining what aberrations in beet-end control are responsible for imperfect first-carbonation control. When these secondary variables have been placed under good control then the alkalimeter becomes of most value as a recorder-controller, giving the best possible alkalinity control. It is not recommended, however, that an alkalimeter be installed unless the secondary variables in carbonation such as first-carbonation temperature, raw juice density and flow, milk of lime flow and lime content, kiln gas pressure and carbon dioxide content are well controlled.

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1944. Ind. Eng. Chem., 36, 574-580.

# Experience in the Treatment of Thick Juice With Calcium Chloride in Operation at Missoula

F. W. Weitz[1]

In a processing procedure patented by C. D. Barber and P. R. Barber of the Menominee Sugar Company (1)[2] and described in a published article by Don J. Barber (2), the addition of calcium chloride to thick juice is recommended for the control of sulfites in sugar and in molasses. Elimination of organic non-sugar matter from the juices by calcium chloride treatment is also claimed.

At the Missoula factory the control of sulfites in the sugar has been an operating problem difficult to cope with. To investigate the possibilities of calcium chloride for dealing with this situation a factory-scale test run was undertaken at Missoula during the 1945 campaign. The results from the test run were sufficiently encouraging so that at the Missoula factory this manner of treatment of the thick juice was continued throughout the balance of the campaign and has since been continued in the subsequent campaigns. The manner of applying the calcium chloride treatment and observation from the trial run in the 1945 campaign are described in the following.

## Manner of Application

The addition of calcium chloride to the thick liquor was started on the trial run on the 38th day of campaign. By that time normal operations had been well established so that the effects of the calcium chloride treatment in processing operations could be observed and proper attention devoted to the test.

The test was begun with the low addition rate of 400 pounds per day, which at the prevailing slicing rate was equivalent to 0.25 pound per ton of beets. Inasmuch as but little was known from experience results, other than those at the Green Bay factory of the originators of this processing procedure, with regard to the proper amount to use for maximum economic benefits, it was purposely intended to start the test using a relatively small amount and then to build up the rate of addition gradually to what would appear to be the optimum. The increase in lime salts in the filtered standard liquor was taken as the basis for determining the optimum addition rate.

The high melter was selected as the place for the introduction of the calcium chloride. The high melt consists of high raw sugar melted in evaporator thick juice. A specially constructed reaction tank, provided with a

[1]General Chemist, American Crystal Sugar Company.
[2]The numbers in parentheses refer to literature cited.

rapid circulation agitator and a constant level overflow, is recommended by the sponsors of the processing method. It was found by experience at the Green Bay factory that unless good mixing and adequate retention for completion of the reaction in the agitator tank is provided, delayed precipitation may cause scaling in the pipe lines. Since the melter at Missoula is equipped with an efficient agitator and is of ample size it was felt that this would adequately serve for the mixing and reaction tank. No additional expense for mixing tank equipment was therefore necessary at Missoula.

The melter is also provided with steam coils and an automatic temperature controller on the steam valve by means of which the temperature of the juice in the tank was maintained at or very close to 97°. The high temperature was probably favorable for flocculation and granulation in the reaction of the calcium chloride with the non-sugars.

Flake calcium chloride, 70 to 72 percent $CaCl_2$, was dissolved in water in a small auxiliary solution tank. In later operations when the flake product was not obtainable fused calcium chloride, 77 to 80 percent $CaCl_2$, was substituted. The fused product was somewhat less convenient to handle than the flakes. It was dissolved by dropping the whole fused mass from a drum into a tank of shallow dimensions, adding water to partially immerse the mass and then agitating with direct steam injection. When the mass was dissolved the strong solution was flowed into the original solution tank provided and then diluted as desired.

A small centrifugal pump connected to the solution tank continuously circulated the calcium chloride solution by drawing it out at the bottom and returning it to the solution tank through an injector. Through a ¼-inch take off from the circulating line, with a valve set to deliver in a continuous stream a predetermined constant amount, the required solution for treatment was drawn off into the thick liquor in the melter.

The calcium chloride solution was made up of such variable concentration so that at the set flow rate through the charging valve the dosage could be adjusted for the slicing rate and the amount desired per ton of beets. This manner of preparing the solution in batches of constant volume, varying the strength to suit the requirements and leaving the valve set for a constant flow rate, was decided upon in preference to the method advocated by the sponsors of the treatment method of making up a solution of constant density and then adjusting the spigot accordingly to deliver the amount desired.

Filter aid slurry, prepared with filtered thick liquor in a separate filter aid mixing tank, was added at the melter in a continuous stream from the slurry circulating line. In the operations at the Green Bay factory, using the calcium chloride treatment of the juice and employing a procedure of pre-coating the press with filter aid, it was found practical to dispense with the subsequent continuous addition of filter aid (2). At Missoula, however, the filter operations indicated that the continuous addition of filter aid was desirable.

The flow of juice at Missoula is from the melter located in the sub-basement to surge tank located on the second floor and thence through the filter feed pump to the presses. The juice is double filtered. No difficulties from pipe scaling were encountered despite the relatively long flow line.

### Filter Operation Effects

The immediate obvious effect on operations following on the start of the treatment of the thick juice with calcium chloride was a marked slowing up of flow through the filters and a very substantial reduction in the length of the press cycles. This condition was not entirely unexpected as some previous warning had been given that such might occur as a result of the mass precipitation of accumulated colloidal gummy materials circulating in process in the remelt stocks.

Under normal operating conditions prior to the test run with calcium chloride addition press cycles on the first liquor were about 40 to 48 hours, with three to four presses on the line. For the first few days after starting the calcium chloride addition the filter service of the presses dropped to cycles of less than 8 hours. A dense smeary type of precipitate was collected on the cloths rendering them almost completely impervious to further filtration after a few hours run. This sludge was indicative of the removal from the juice of a substantial amount of gum-like organic non-sugars still remaining despite the normal lime defecation and carbonation and the filtration of the thin juice.

To assist in the filtration under these difficult conditions first encountered a supplemental dosage of filter aid was added directly into the outlet well in the first liquor surge tank each time a clean press was put on the line. By forcing a rapid flow through wide open valve into the new press while pinching back at the same time on the old presses, a moderate pre-coat was formed. In later operations a separate pre-coat mixing tank was provided, which then afforded improved facilities for more efficient pre-coating of the filters. This moderate pre-coating effected by the first makeshift arrangement significantly improved the flow through of juice, but despite this aid the filter cycles were still discouragingly short.

With determined effort, in the face of the obvious filtration difficulties, to carry the test through at least one round of crystallizers, presses were cleaned as often as necessary, frequently two or three a shift. After about the fourth day of the test run gradual improvements in flow rates and press cycles were noted.

The rate of calcium chloride addition was then stepped up slightly for the next few days to a dosage of about 0.4 pound per ton of beets sliced. Since no relapsing detrimental effect with respect to filterability of the juice was noted due to the increased dosage of calcium chloride, but that rather filtration improvement was observed, the dosage was subsequently raised by increments until towards the latter part of campaign a dosage of slightly over 1 pound per ton of beets was being used.

After the first 2 weeks or so of struggling with filtration difficulties under the calcium chloride treatment the filter flow rates and the press cycles were restored again to satisfactory operating performance. Due to the greater amount of solids removed a regular schedule was set up to pull each press on a 24-hour cycle, staggering the start of the three presses on the line at 8-hour intervals.

For the Missoula conditions, judged on the basis of the increase in lime salts in the filtered standard liquor, 0.9 pound calcium chloride per ton of beets sliced was considered about optimum. In the later stages of the test period, when the calcium chloride addition was in excess of 1 pound per ton of beets, the lime salts, normally at a very low figure at that factory, had increased to nearly double of the 0.008 weekly average shown in the period just prior to the start of the treatment. Whether a moderate increase in lime salts resulting from the calcium chloride addition would necessarily be harmful in causing scaling is doubtful. As chlorides, the lime salts would not be scale forming. In appreciable excess the added lime salt might hinder boiling and retard crystallization.

## Sulfite Reduction

As concerns the results achieved in the line of the primary purpose for which the calcium chloride treatment of the juice was advanced, that of lowering the sulfites in the first liquor for final products of sugar and molasses with lowered $SO_2$ content, it was apparent that the treatment had been effective. In the first liquor, with weekly averages of 800 to 900 parts per million $SO_2$ prior to starting treatment with calcium chloride the $SO_2$ content in the latter stages of the test run had dropped to about 400 parts per million.

Sulfites in the sugar produced at Missoula have generally been quite high. During the period of the test run a marked decrease in the sulfites in sugar produced was noted, with an average for a weekly period as low as 6 parts per million.

Likewise in the molasses a reduction in sulfites was obtained. The average of daily tests on molasses produced for the weekly period prior to starting with the calcium chloride treatment of the juice was in the range of 8900 parts per million $SO_2$. During the final weeks of the test run the sulfites in molasses were down to about 2400 parts per million.

Sugar ash followed somewhat the same pattern as the sulfites in the sugar during the test run. Starting with an ash of 0.016 and 0.013 percent, respectively, as the weekly averages on sugar produced in the 2 weeks before starting the treatment of first liquor with calcium chloride, the ash decreased to 0.010 in the latter weeks of the run. Comparative operating and test data are given in table 1.

Table I.—Comparative operating and test data relative to calcium chloride treatment of thick juice at Missoula.

| Weekly averages | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Analysis | | | | | |
| | | | | $SO_2$ | | PPM | | |
| Week ending 1945 campaign | Beets sliced per day (tons) | Calcium chloride per ton beets (pounds) | Sugar ash (percent) | First liquor | Sugar | Molasses | Lime salts first liquor | Molasses percent on beets |
| Oct. 28 | 1429 | None | .016 | 828 | 25.5 | 8900 | .008 | 4.13 |
| Nov. 4 | 1286 | None | .013 | 888 | 14.5 | | .008 | 3.62 |
| Nov. 11* | 1510 | .15 | .012 | 966 | 16.1 | | .013 | 4.00 |
| Nov. 18 | 1534 | .51 | .013 | 733 | 16.8 | | .010 | 4.21 |
| Nov. 25 | 1512 | .89 | .010 | 453 | 9.4 | 3668 | .012 | 3.72 |
| Dec. 2 | 1502 | .93 | .010 | 340 | 6.3 | 2378 | .014 | 4.20 |
| Dec. 9 | 1521 | 1.05 | .011 | 442 | 14.2 | 2429 | .014 | 4.20 |

*Calcium chloride addition started November 8.

## Effect of Raw Fillmass

Quite aside from the beneficial effects in reducing sulfites in the end products, a supplementary, but equally, and probably more important result achieved, considered from the operating standpoint, which was very obviously associated with the calcium chloride treatment of the first liquor, was the pronounced freeing up of the raw fillmass. The Missoula raw fillmasses were notably sticky and difficult to purge. The improvements in the pan boiling characteristics of the low purity green syrups and the spinning qualities of the crystallizer fillmass in the centrifugals following the use of calcium chloride in the first liquor were unmistakable. The usual former stickiness and stringy, gummy characteristics were largely eliminated. Color also had improved. The effect was so apparent and so favorable that the operators accustomed to the former sticky masses spoke of it as remarkable.

This feature in itself as concerns the improvement in the workability of the low grade products is considered now the more important advantage and has merited the continuance of the calcium chloride treatment of the first liquor at the Missoula factory.

## Experience at East Grand Forks Factory

Without detracting in any way from the obvious merits of the calcium chloride treatment of juices observed in operations at Missoula, the citation of those experiences would not be complete without reference to the less favorable experience in attempts made at introducing the like processing treatment at the East Grand Forks factory. In several different starts made at that factory in successive campaigns, filtration difficulties encountered were such that it was practically impossible to keep up the juice flow through the filters and the trials had to be discontinued.

To insure most favorable conditions after the first unsuccessful start at using calcium chloride in the juice at East Grand Forks, the special mixing tank recommended was built and installed but this did not relieve the filtration obstacle. The smeary, gummy residues deposited in the filters

were evidence that the treatment with calcium chloride was coagulating organic non-sugar matter in the juice, the removal of which undoubtedly would have been beneficial. The practical operating difficulties, however, in those attempts at East Grand Forks, required the interruption of the treatment before the possible benefits to be derived at that factory in subsequent processing could be ascertained or realized in the manner as profitably experienced at the Missoula factory.

## Summary

The treatment of first liquor with calcium chloride ahead of filtration at the Missoula factory proved effective in reducing sulfites in granulated sugar and in molasses. Coagulation of organic non-sugars of a gummy nature by the calcium chloride treatment initially caused filtration difficulties. The elimination of the organic non-sugar material improved the purging qualities of the raw fillmass. A dosage of about 0.9 pound of calcium chloride per ton of beets sliced was found to be optimum for Missoula conditions without unduly increasing lime salts in the filtered first liquor. Filtration difficulties in trial runs at East Grand Forks prevented the adoption of the process of calcium chloride addition in operations at that factory.

# Continuous Sugar Detector

RUDOLPH H. LARSEN[1]

THE ESTIMATION of sucrose by the Molisch Reaction is well known to all of us. Many attempts at improved methods, or apparatus, had produced nothing of importance until the Continuous Sugar Detector was invented by P. W. Alston and E. E. Morse (U. S. Patent 2,408,900) of the Spreckels Sugar Company. The predecessor to the continuous sugar detector, for testing of various vapors, was the intermittent method. This apparatus has been mentioned in literature of Germany and the United Kingdom. It is non-continuous in operation; e.g., a fixed amount of condensate water was run into the cell, alpha napthol solution added and sulphuric acid run in, in consecutive steps. The intensity of the colored reaction products was measured by a photocell, then the cell was emptied and rinsed. Needless to say, this type of detector never came into prominence in that it was but slight improvement over a hand test by Molisch Reaction, and also to the fact that it was non-continuous.

The Continuous Sugar Detector is continuous in every respect, in that a continuous flow of condensate is constantly being run into the detector, together with a continuous feed of sulphuric acid and alpha naphthol. The reaction is continuously taking place as long as there are any sugars present. The colored reaction is constantly measured and the results recorded.

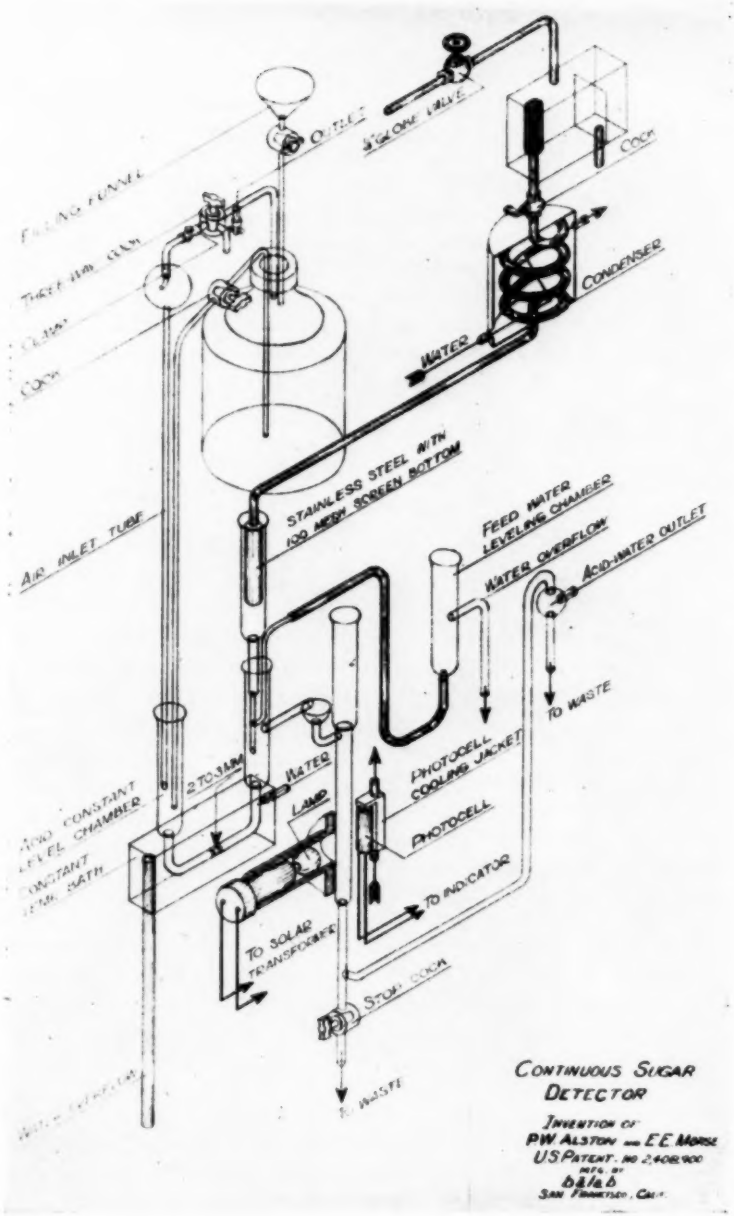
## Various Components of Continuous Sugar Detector and Their Operation

A. Feed water portion.
   1. Filter paper.
   2. Throttling valve for overflow chamber.
   3. Constant head and overflow-control box.
   4. Cooler.
   5. Filter screen.
   6. Condensate flow-control nozzle.

B. Acid, alpha naphthol feed portion.
   1. Reservoir.
   2. Feed-control portion.
   3. Orifice to limit acid flow, and cooler.
   4. Alpha naphthol and sulphuric acid.

C. Reaction chamber.
   1. Chamber where condensate and acid-alpha naphthol mixture comes together.

[1]Field Chemist, Balab "Bubble-Breaker" Defoamer Division.


CONDENSER
WATER
STAINLESS STEEL WITH 100 MESH SCREEN BOTTOM
AIR INLET TUBE
FEED WATER LEVELING CHAMBER
WATER OVERFLOW
ACID-WATER OUTLET
TO WASTE
PHOTOCELL COOLING JACKET
PHOTOCELL
TO INDICATOR
LAMP
TO SOLAR TRANSFORMER
CONSTANT LEVEL CHAMBER
CONSTANT TEMP. BATH
STOPCOCK
TO WASTE
CONTINUOUS SUGAR DETECTOR
INVENTION OF
P.W. ALSTON AND E.E. MORSE
U.S. PATENT NO. 2,408,900
MFG. BY
D & A B
SAN FRANCISCO, CALIF.

D. Absorption chamber and illuminant system.
   1. Light source.
   2. Photo-electric cell.
   3. Warning signal.
   4. Recording, or indicating, apparatus.

A. *Discussion of Feed Water Portion*

Second condensate, or other solution or solutions, to be tested is obtained through a 1/8-inch line from the discharge of the condensate pumps. The flow is controlled by a valve near the apparatus; the condensate is first filtered and then passes into a small, constant level box with an overflow. From this box the water runs into the cooler through a control valve. The cooler is a heat exchanger with a cylindrical outer casing 4 inches in diameter by 10 inches long. It contains a 12-foot coil of 1/4 inch O. D. copper tubing, and is considerably over-designed as to capacity. The condensate must be cooled to approximately room temperature to enable the color reaction to take place. The cooling system is supplied with water from the domestic house cold-water system. From the cooler the condensate flows through a fine screen and into the nozzle tube. A feed water leveling chamber is used to control the head on the nozzle. For the nozzle a piece of 7-millimeter glass tubing is drawn out and a tip formed so a 4-inch head of cooled condensate on the nozzle will deliver, into the air, 15 milliliters per minute.

B. *Sulphuric Acid—Alpha Naphthol Portion*

As a reservoir for the acid mixture a 5-gallon Pyrex bottle is used; the acid and alpha naphthol are mixed in the proportion of 1 gram of alpha naphthol to 1 pound of acid. To facilitate mixing, the alpha naphthol is dissolved in methyl alcohol. The mixture must be shaken up immediately; otherwise an insoluble solid is formed, the nature of which is unknown. A mixture so prepared will have identical reaction properties over an interval of at least a week. The acid used is nitrate free sulphuric acid, regular CP—ACS standard. The alpha naphthol used is special alpha naphthol for sugar testing.

C. *Reaction Chamber*

The acid is delivered to the constant-level chamber by means of a siphon line. In order to limit the acid flow it is necessary to have a constriction in the tube leading to the reaction chamber. The constriction in this tube is 2 millimeters; the tube is cooled by means of a condenser which is blown around the constricted tube. The reaction chamber is the place where the acid, alpha naphthol and condensate come together; the condensate from the nozzle should "plow up" the acid level to a depth of about 1/8-inch under the interface.

D. *Absorption Chamber and Illuminant*

An overflow takes place from the reaction chamber to a tube which passes a photo-electric cell, by which the intensity of color is measured. The illuminant in this case is a 100-watt bulb mounted in a sliding receptacle to actuate the cell properly. The electrical supply is maintained uniformly by means of a constant voltage Sola transformer.

Since great heat is evolved in this reaction and photocells, of the type used are damaged by temperatures above 120° F., it is necessary to water-jacket the photocell housing; and also, the detector may be placed in the mill, the house temperature of which can well be 120° F., so hence the cell must be cooled.

D-4. *Recording or Indicating Apparatus*

The output of the photo-electric cell is brought out to a Brown Electronik Continuous Balance Potentiometer instrument. The instrument is provided with a suitable calibration to match the photo-electric cell output and is calibrated in parts per million of sugar. It contains a large indicating pointer that can easily be seen to distances up to 150 feet. It also gives a record of the condition of the boiler feed water over a 24-hour period. The instrument responds immediately to any unbalance that is transmitted by the photocell. In terms of pointer travel the large black indicating pointer travels from 0 on the scale to full scale in 12 seconds. That is the speed that the driving unit is capable of moving the recording mechanism and the indicating pointer. However, in all normal applications, this speed is more than ample since there is no lag in the instrument between the time the unbalance occurs and movement of the pointer begins.

The instrument can be purchased in the form of an indicator or recording instrument. The recording instrument is available in any type of control form, either air or electric actuation. The indication type of instrument is only available in electric control form. The control on the instrument can be used to sound an alarm and to indicate on an alarm light when the sugar content has reached a dangerous level. It can also be used to immediately stop the flow of boiler feed water by means of closing a shut-off valve and at the same time open a feed-water valve from an unpolluted source. Or it can operate a mixing valve that will mix the feed water from various sources so that the sugar content can be held to a predetermined maximum. The controller can be provided with either an internal or external control point setting so the alarm contact or the control contact will actuate at any value that has been determined to be the maximum safe value for the boiler in question.

## Maintenance and Cost of Operation

Over a 24-hour period the approximate cost of acid, alpha naphthol and labor amounts to $4.00. This cost is figured on use of 9-pound bottles of

sulfuric acid, but cost can be reduced considerably by purchasing sulfuric acid in carboys. However, 9-pound bottles are preferred for convenience of handling and safety.

### Replacement of Light Source

The 100-watt bulb should be replaced when there is a noticeable darkening of the bulb.

### Conclusion

The present continuous sugar detector has been in successful operation at three Spreckels Sugar Factories for a period of 7 years. When this instrument has been in use no shut down of boilers, due to sugar in the condensates, has been experienced. Thus, the instrument easily pays for itself, as one flash of sugar in the condensate could cause a shut down amounting to several thousand dollars. The general field and use of the continuous sugar detector should be more than ever now, especially with the advent of high pressure steam generating plants. Needless to say a factory can ill afford to take a chance on having sugar in condensate cause a costly shutdown.

# Pulp Press Water Reclamation

W. O. Weckel[1]

Under the modern concept of industrial practice, economical use of fresh water supplies and reduction of waste disposal have become of extreme importance. This is particularly true in the beet sugar industry where large amounts of fresh water are required and the disposal problem of each plant is equivalent to that of a fair-sized city. The two problems are closely related in that a reduction of water usage results in a lower volume of waste to be handled. In general, the best and cheapest method of attacking a waste-disposal problem is to first eliminate or reduce as much of the waste as possible.

The advent of utilization of by-products from Steffen waste and the use of continuous diffusion units for extracting sugar from beets have improved the picture greatly. Now the overall problem of waste disposal and water usage may be more realistically handled.

One of the chief wastes still requiring disposal facilities under these conditions, is pulp press water. This water, while not extremely large in quantity, is high in both solids and organic matter, hence high in B.O.D content.

## Previous Work

During recent years, a considerable amount of work has been done in Europe on the return of both pulp water and pulp press water to the diffusion batteries. The literature on this subject is quite fully discussed by Wintzell and Lauritzson (6).[2] Most of the work on this subject has been with returning pulp water to the battery and in addition some have tried returning pulp press water with and without treatment.

On the basis of previous work done by others and their own work, Wintzell and Lauritzson concluded that:

1. Pulp water if sufficiently well screened can be returned to the battery separately without visible corrosion, harmful effect on battery operation, or harmful effect on juice quality.

2. By returning the pulp water, all the sugar solids and harmful nitrogen appeared to have been transferred to the pulp. The net gain was a considerable reduction in solids sewered, and a corresponding gain in pressed pulp solids without ill effects to the process.

Following two successful seasons of operation using the return of pulp water only, they instituted the total return of pulp and press waters, using an acid defecation of the latter.

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[1]Chief Chemist, Spreckels Sugar Company, Spreckels, California.
[2]The numbers in parentheses refer to literature cited.

Wintzell and Lauritzson were issued patents (7) covering this acid treatment of press water which has as its essential points:

1. Addition of sulfuric acid to a pH of about 3.6
2. Clarification to separate the precipitated floc, and,
3. Centrifugal separation of the sludge.

On the basis of comparative tests, Wintzell and Lauritzson claimed the following results as compared with no return of the pulp or press water:

1. No corrosion if precaution is taken to exclude air from the acid waters and to remove sand.
2. No serious foaming if precaution is taken to avoid splashing.
3. Slight increase in battery capacity.
4. Sugar loss reduced by 0.10 percent on beets with 2 percent less draft.
5. No detectable inversion in returned water.
6. No significant change in juice quality.
7. Pulp solids increased by 0.8 to 1.0 percent on beets.
8. Pulp presses worked easier and pressed pulp moistures were reduced 1.2 percent.

Other writers, notably Backmann (1), Wescke (5), and McDonald (3) have since criticized the Wintzell-Lauritzson process as causing excessive corrosion in handling the acidified press water. McDonald (2) suggested that instead, the pulp and press water be limed to 7.0 pH and sterilized at 90 degrees centrigrade immediately before use in the battery.

Previously, various other people had tried the use of lime treatment of press water but it met with disfavor principally because of the effect of slowing the diffusion rate and the amount of nitrogen compounds returned.

## Preliminary Experiments

An alternative use for lime treated press water is in the various points in the Steffen process. Most of the experiments made by the Spreckels Sugar Company in this field have been directed toward this end.

In 1939, preliminary laboratory experiments were conducted which showed that good defecation could be obtained using 0.2 percent CaO addition. The floc settled satisfactorily and was filterable through ordinary filter paper. The addition of 0.5 to 1.0 percent lime cake sludge, either before or after the lime addition, improved the settling rate and did not contribute soluble solids. The lime defecation also effectively stopped bacterial action in the clarified water. These tests indicated that the defecated water may be suitable for Steffen use.

Accordingly, a temporary installation was made in which a portion of the screened press water was piped to a spare Steffen Dorr clarifier. Upstream from the clarifier, milk of lime was added at the rate of about

0.2 percent CaO on press water. Some trouble was experienced with obtaining uniform lime addition because of the temporary arrangement. However, uniform lime addition was found to produce satisfactory clarification.

Because of the high temperature (50 to 55 degrees centigrade), of the clarified press water, it was not possible to use the entire available quantity in the solution mixer, however, on two occasions, the Steffen operating rate was reduced by half, to enable a test to be made. No adverse effects on cake purities or losses were detected. Plugging of the cold filter cloths resulted, if the returned water was allowed to become cloudy; however, with proper clarification of the returned water, the filters were not affected.

In 1940, laboratory experiments were made on washing cold cake with warm, defecated pulp press water. The conclusion was reached that no decomposition of the saccharate resulted from the use of the warm water nor was anything precipitated in the cake which might retard filtration. Drying of the cake following washing was more rapid when using the clarified press water in place of cold tap water.

### Settling Tests

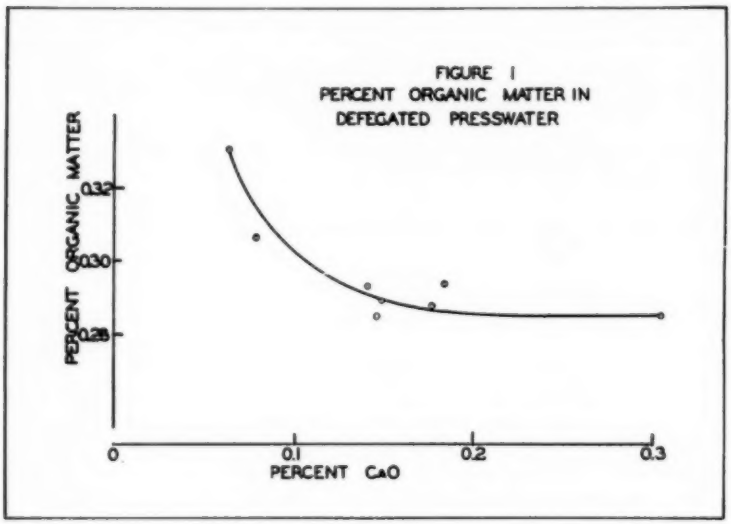
In 1947, experimental work on the subject was continued to obtain more complete information. Settling characteristics were studied in greater detail using the method described by Skaar and McGinnis (4). Preliminary bench tests indicated some differences in the settling characteristics between batch and continuous defecation so a continuous bench-scale apparatus was set up for subsequent work. Continuous operation showed improved settling against batch operation and would be much more practical in plant-scale work.

The first phase of the problem studied was the lime addition required to produce satisfactory settling and purification. Variations in press water were found to require somewhat different amounts of lime. The results obtained indicated that 0.15 percent CaO was a safe minimum addition for practically all conditions encountered. Additional liming showed no improvement in settling rate or degree of clarification. The quantity of organic matter remaining in the supernatant liquor was used as a basis for judging the degree of purification. This was also found to be quite constant beyond the previously mentioned safe minimum lime addition. Figure 1 shows a typical example.

After having determined the effect of adding various quantities of lime, recirculation was the next variable studied. This was found to be a negligible factor. Recirculation as high as ten-to-one ratio yielded no improvement in settling rate and organic matter removal.

Retention time was also tested. Somewhat as in the study of lime addition, retention beyond 4.5 minutes added no improvement to settling rate or removal of organic matter. Possibly more efficient dispersal of the lime would shorten this time as it appeared that adequate mixing was the most important factor.

The settling character information obtained in the three series of tests just mentioned was checked in a pilot installation. The results produced in the pilot plant were considerably better than the bench tests. A settling rate of 1.16 gallons of feed per minute per square foot of area was obtained at a ratio of 85 percent clear effluent to 15 percent underflow. The underflow contained 1.5 to 2.0 percent suspended solids.




## Filtration Tests

A few filtration tests were conducted on the sludge in a bomb-type filter. Because of the compressibility of the cake, it was soon found that only small to moderate pressures could be tolerated in filtration. Fifteen inches of mercury pressure appeared to be optimum. At this pressure, a filtration rate of 6.2 gallons per hour per square foot of filter surface was obtained on a 30-minute cycle. These tests were all made at 50 degrees centigrade. A comparative test at 80 degrees centigrade was also made. This showed an increase in rate to 8.5 gallons per hour per square foot of filter surface.

The cake obtained in the filtration tests appeared very bulky and of a low solids content. Following one of the regular tests, the filter leaf was excessed with air at filtration pressure and the cake was dried to a solids content of 20 percent.

As a whole, the filtration tests should be viewed as being directional rather than specific data. Because of the lack of facilities, it was necessary to transport preserved material from one factory to another for the tests. This makes it impossible to say no change had occurred.

## Utilization

Before the clarified press water can be effectively utilized for diluting molasses in the Steffen process, it must be cooled to a temperature approaching cold water temperature. Otherwise excessive refrigeration equipment would be necessary. This can be done most economically by a cooling tower. However, with a considerable amount of sugar and other organic matter present, it seemed possible that algae growth might present a problem in such a cooling tower. In order to check this point, a pilot cooling tower was built and operated continuously with clarified press water for 3 weeks. No evidence of algae formation was found. The clear effluent remains at approximately 12.0 pH and it seems unlikely that any algae could survive in this water.

In order to determine more accurately the effect of using clarified press water in the Steffen process, a large sample was concentrated to 6.5 percent sugar. This solution had an apparent purity of 87. Cold saccharate cake produced from this solution had an apparent purity of 96.7. Incidentally, it may also be noted here that the beets from which the press water was derived were piled beets and in poor condition. Therefore, it appears that in a conservative view, Steffens purities would not be degraded by the use of clarified press water.

## Summary and Conclusions

As a whole, the tests made, clearly indicate that pulp press water can be treated successfully by means of lime defecation. The lime required is approximately 0.15 percent CaO on water. Other factors such as recirculation and retention time appear to be insignificant as long as sufficient mixing occurs prior to settling. The best settling area requirements obtained in pilot-scale tests were 1.16 gallons per minute per square foot of area at a ratio of 85 percent clear effluent to 15 percent underflow. Filtration requirements on this underflow were the only important factors not explored sufficiently. The clarified water can be successfully used in the Steffen process after cooling. This pre-cooling before refrigeration may be accomplished by means of a cooling tower without excessive algae formation.

As benefits to be derived from such a system we believe the following may be accomplished:

1. Recovery of high percentage of the sugar now lost in pulp press water.
2. Increased dried pulp solids production by return of the filtered sludge to the pressed pulp.
3. Increased amino acid content of Steffen filtrate and,
4. Reduction in both water consumption and waste disposal.

These factors exist with the either batch or continuous diffusion. Where conventional Robert-type batteries are in use, this treatment in

conjunction with pulp water return to the battery should make possible even greater sugar recovery. As demonstrated by Wintzell and Lauritzson, much of the pulp water sugar would be transferred to the pulp and be recovered in the press water.

The degree of completeness of the utilization in the Steffen process will depend upon the ratio of molasses worked to beets sliced. For complete reuse of the press water, it will probably be necessary to use it for slaking lime and washing the cold cake in addition to molasses dilution.

The financial savings will vary considerably according to factory conditions but in general they appear to be quite attractive.

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# A Small-Scale Technique for Simulating Large-Pile Conditions in Cooling and Storing Sugar Beets

MYRON STOUT[1] AND C. A. FORT[2]

THE PRIMARY PROBLEM in reducing sugar losses during storage in commercial piles of sugar beets is to find a practical means of reducing the temperature of the beets and to find a way to eliminate "hot spots" that are usually caused by the presence of excessive amounts of trash and dirt in parts of the pile. It is practically impossible to cool storage piles by means other than the circulation of cool air through the piles. Since night temperatures during the warmer part of the storage period are usually 20 degrees to 35 degrees Fahrenheit cooler than day-time temperatures, rapidly increasing use has been made by the industry of the method of forced ventilating beets with cool night air, demonstrated by the writers in 1945 (1).[3]

Recognition of the large quantities of heat given off by commercial storage piles of beets (2) and the important influence that temperature has on respiratory heat output makes it necessary that we accumulate technical data to answer some of the following questions:

1. Since respiratory heat rises progressively through upper layers of beets in a pile what is the practical limit to height in relation to cooling with forced ventilation?

2. How much resistance does a normal column of beets have to different rates of air flow? What effect does dirt and trash have on air flow when uniformly distributed and when relatively concentrated?

3. How much natural draft is induced through piles at various temperature differentials inside and outside the piles?

4. What is the lowest temperature than can be safely used to force-ventilate beet piles? Is the safe temperature related to beet turgidity and if so to what extent?

5. How important is evaporative cooling to the forced-ventilation method of cooling beets?

6. What is the relationship of temperature, relative humidity and dew point to cooling efficiency?

It is obvious that information regarding most of these practical questions can not be secured unless the amount of air in relation to the tonnage of beets is known with some degree of accuracy, and also unless the path

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[3]The numbers in parentheses refer to literature cited.

of the air-stream is confined to the beets under study. Commercial piles of beets do not allow such restrictions and are, furthermore, too expensive to use for some of the experimental treatments. The described research equipment was designed to gain as much technical information as possible without using large tonnages of beets.

Two insulated storage columns were constructed in three sections each. A general view of the columns and accessory equipment is shown in figure 1. Each section is 8 feet high, 3 feet inside and 44 inches outside diameter.

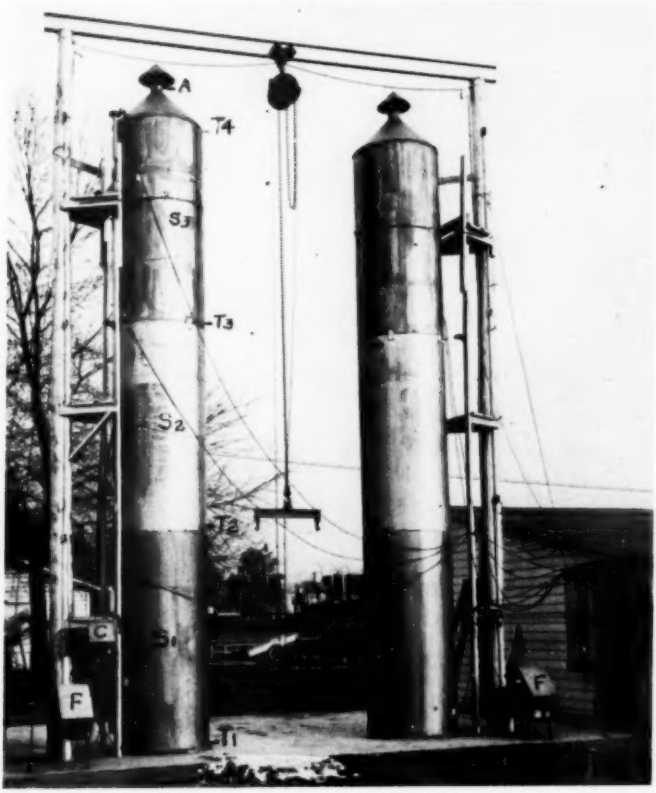


Figure 1.—Experimental sugar beet storage columns with accessory equipment.

A. Anemometer and automatic closure (closes when not ventilating) $T_1$, $T_2$, $T_3$, $T_4$—Elevations for measuring beet temperatures, air pressures, wet and dry bulb temperatures of ambient air by means of Friez electrically ventilated psychrometer. $S_1$, $S_2$, $S_3$—Eight-foot sections. C. Thermostatic controls (mercoid—2 in series to run blower only between set temperatures, e. g. 26°-33° F.). F. Multi-blade blowers. R. Resistance thermometer recorder. T. Three-pen recorders record temperatures of air at top and bottom of columns as well as outside air temperatures.

Four inches of rock-wool insulation are packed between the inside and outside shells which are made of $\frac{1}{8}$-inch steel plate. Grating bars 6 inches apart and 2 inches high in the bottom support 2-inch mesh wire screen on which the beets are placed in each section. Each section is, therefore, independent as far as filling, weighing and emptying the beets is concerned. Each section weighs about $\frac{1}{2}$ ton and holds slightly more than 1 ton of beets when fully filled.

Resistance thermometers are inserted through 1-inch pipes 1 foot from the base of each section. Each thermometer is inserted in the center of a beet and the temperature is continuously recorded on a strip chart multiple recording instrument. Air temperature, pressure, humidity and dew point of the ambient air are made through another 1-inch pipe near the base and extending between the grating bars to near the center of each section and also in the top of each column. Four short strap-iron guides, welded to the top of each section allow the sections to be stacked upon each other without slipping. An air-tight seal between sections is made by means of caulking putty. Strap-iron loops inside and near the top of each section provide means of attaching the 2-ton chain blocks for lifting. The chain blocks are attached to a trolley mounted on an 8-inch "I" beam between two 28-foot poles spaced 19 feet apart. Each column is 24 feet high and covered by an insulated cap equipped with a ring for sealing to an anemometer for measuring air flow through each column.

Ambient air temperature, humidity, dew point, and moisture content measurements are made by means of an electrically ventilated psychrometer attachable to the base of each section and cap. Attachment is made through a flexible gas mask tube. Evaporative cooling can be calculated by the moisture content increase between any points in the column. This determination has been simplified by preparing a table of the moisture content in pounds per 1,000 cubic feet of saturated air at different temperatures (3). The amount in saturated air multiplied by the percentage relative humidity equals the moisture content at any given conditions. (table 1).

Multi-blade blowers deliver air to the bottom of each column through 6-inch tile pipes set in the concrete slab. The blowers are driven by electric motors equipped with adjustable "V" belt pulleys. The motors are located outside the ventilating air-stream. The inlet side of each blower is equipped with a metal ring suitable for attachment to a humidity chamber or air-washing device. Adjustable dampers regulate the air supply to the blowers.

To gain the maximum value of cooling temperatures available without injuring the beets, one fan motor has been connected through two mercoid thermo-regulators connected in series. The mercoid switch is reversed in one regulator. One regulator turns on at temperatures below a set maxi-

mum (e.g. 33° F.), the other regulator stays on until a set minimum (e.g. 27° F.) is reached. Since the two regulators are connected in series and are on simultaneously only between 33 degrees and 27 degrees Fahrenheit, the beets are ventilated only between these set temperatures. A counterbalanced damper closes the column when the blower is off to prevent circulation of air that is too warm or too cold.

**Table 1.—Weight of 1,000 cubic feet of saturated aqueous vapor at different temperatures.**

| Temperature °F. | 0.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 |
|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 10 | 0.111[1] | 0.117 | 0.122 | 0.128 | 0.134 | 0.141 | 0.147 | 0.154 | 0.161 | 0.169 |
| 20 | 0.176 | 0.185 | 0.194 | 0.203 | 0.212 | 0.222 | 0.232 | 0.242 | 0.253 | 0.265 |
| 30 | 0.276 | 0.289 | 0.302 | 0.313 | 0.326 | 0.338 | 0.351 | 0.364 | 0.378 | 0.392 |
| 40 | 0.407 | 0.422 | 0.438 | 0.454 | 0.471 | 0.488 | 0.506 | 0.524 | 0.543 | 0.562 |
| 50 | 0.582 | 0.603 | 0.625 | 0.647 | 0.669 | 0.693 | 0.717 | 0.742 | 0.767 | 0.794 |
| 60 | 0.821 | 0.849 | 0.877 | 0.907 | 0.938 | 0.969 | 1.001 | 1.034 | 1.069 | 1.104 |
| 70 | 1.140 | 1.177 | 1.215 | 1.255 | 1.295 | 1.337 | 1.379 | 1.423 | 1.468 | 1.514 |
| 80 | 1.562 | 1.611 | 1.661 | 1.712 | 1.765 | 1.819 | 1.875 | 1.932 | 1.991 | 2.051 |
| 90 | 2.113 | 2.176 | 2.241 | 2.308 | 2.376 | 2.446 | 2.518 | 2.592 | 2.667 | 2.745 |

[1]Values in this column are for the temperatures 10°, 20°, 30° F., etc. The interpolated values are shown in the other nine columns.

Use of table: To find, for example, the weight of aqueous vapor in 1,000 cubic feet of air at 36° F. and 78 percent R.H., take the value from the table at 36°F, which is 0.351, and multiply by 0.78.

0.351 x .78 = 0.274 pounds per 1,000 cubic feet.

## Experimental Results to Date

The experimental equipment described was obtained too late for many of the studies planned for the first year. All beets were at temperatures near the freezing point when the columns were filled November 21, 1947. However, air-resistance data, natural ventilation rates in relation to temperature and limited data on moisture content of the air passing up through the column at different rates can be reported. A few other observations that may aid further planning are reported. Air was blown through the empty column at rates up to 150 cubic feet per minute and the pressures were carefully measured. Tinted xylol (Sp. G. 0.86) was used in the manometers. Air was again blown through after filling each column with 3 tons of unwashed beets. Graphs were prepared from the pressure and rate of ventilation data. Pressures for a given rate of ventilation were read from the graphs. The pressures measured at the different levels of the empty columns were the same for a given rate of ventilation because practically all resistance was caused by forcing the air through the 4-inch annemometer openings in the top. When the columns were filled with beets the pressures progressively decreased from bottom to top, the pressure in the top of the column was the same as that for the empty column. The data in table 2 are therefore, pressures at the base of the columns expressed in inches of water pressure.

Table 2.—Air pressure at various ventilation rates at the base of a 24-foot column containing 3 tons of sugar beets.

| Cubic feet per minute | | Inches water pressure at base of column | | |
|---|---|---|---|---|
| Total | Per ton of beets | Empty column | South column filled | North column filled |
| 25 | 8.3 | 0.01 | 0.01 | 0.02 |
| 50 | 16.7 | 0.02 | 0.04 | 0.05 |
| 75 | 25.0 | 0.04 | 0.07 | 0.08 |
| 100 | 33.3 | 0.07 | 0.11 | 0.13 |
| 125 | 41.7 | 0.11 | 0.17 | 0.20 |
| 150 | 50.0 | 0.17 | 0.26 | 0.28 |

It can readily be seen from the data in table 2 that resistance to the flow of air in a column of beets is practically neglible unless excessive trash is present. Even at a rate of 150 C.F.M. the resistance of the beets amounted to only 0.09 to 0.11 inch water pressure. The mean velocity of air through the column filled with beets was only 53 linear feet per minute at a ventilation rate of 150 C.F.M. Since beets are quite large in size and actually occupy only about 60 percent of the volume of a filled column the airspaces are relatively large. The low pressures developed are perfectly reasonable.

Natural draft of air through the columns of beets was measured at several inside and outside temperatures. The direction of flow depended on the direction of the inside and outside temperature differential. For example, when the average temperature differentials between beets and outside air were 4.5 degrees and 8.5 degrees Fahrenheit the corresponding natural ventilation rates were 15 and 28 C.F.M. respectively. This further indicates very free circulation of air.

The consistency and precision of the determination of the total water content of air was greater than expected. At wet-bulb temperatures above 32 degrees Fahrenheit this determination is rapid and fairly reproducible.

It was observed that moisture uptake was quite rapid at normal ventilation rates in columns of beets and that the moisture uptake between different elevations could be determined with a fair degree of accuracy. If a relatively constant degree of saturation of the air is attained under dry-air conditions it should be possible to approximately calculate the evaporative cooling obtainable under more humid conditions and thus make data obtained at Salt Lake City useful for other climates. This observed rapid moisture transfer also indicates some danger from ventilating cold beets in the bottom of a pile with air having a higher dew point than the bottom beets. Such a practice would moisten the surfaces of the beets and enhance the development of molds.

The beets were kept in the columns until April 21, 1948, a total of 152 days. From February 3 one column (south) was left open to natural ventilation and the other (north) was thermostatically controlled. The north column was ventilated only between set temperatures. The lower limit was set at 25 degrees Fahrenheit and the upper limit was set at 34 degrees Fahrenheit until March 16. As warmer temperatures prevailed the upper limit was raised. The volume of air used was 35 C.F.M. per ton of beets.

On the morning of February 12 the air temperature was as low as 4 degrees Fahrenheit. At 8:00 a.m., when the air temperature was 10 degrees Fahrenheit, 30.4 C.F.M. of air was flowing up through the 4-inch outlet of the south column. The beets in the bottom of this naturally ventilated column reached a temperature of 18 degrees Fahrenheit. Although the beets for about 2 to 3 feet up in the column were frozen the losses were not as great as expected. Two samples of these previously frozen beets showed 13.5 percent and 12.7 percent direct polarization (as recovered basis). The beets above this point were in excellent condition.

Greater weight and sugar losses occurred in the north column indicating that the beets in that column were ventilated excessively. The total sugar losses (direct polarization) in pounds per ton per day in the top center and bottom sections, respectively, were 0.224, 0.313 and 0.256 for the north column and 0.154, 0.107 and 0.285 for the south column. Reducing sugar determinations showed that the respiration loss was higher in the north column and the inversion loss was greater in the south column.

No mass spoilage occurred in either column except for the greater losses shown by the frozen beets in the south column. Only a few individual beets were partly or almost completely spoiled. Beets next to spoiled ones were apparently healthy, indicating very little transfer of spoilage but rather that some beets were much less resistant to spoilage or possibly had been slightly frozen before they were placed in the columns.

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# Michigan State College Sugar Beet Storage Experiment

C. M. HANSEN[1]

THE PROBLEM of storing sugar beets at the processing plant without sugar loss has long been recognized in the Eastern area. The acceptance of the harvester has made this problem more acute. The farmer wants to deliver his beets as fast as he can harvest them. Consequently, proper means must be found to receive and store the beets until such a time as the plant can process them. Often this period is marked by "Indian Summer" temperatures which do not go below 65 degrees Fahrenheit. Data collected by Stout and Fort (4)[2] shows that beets stockpiled during warm periods will lose sugar at the rate of ¼ to 1 pound per ton of beets per day depending upon the prevailing temperature. The magnitude of this problem is realized when we consider the Eastern Area crop stored over a period of 30 days. The storage period with damaging temperatures has resulted in a loss of approximately $1,500,000 per year for the past several years.

Engineers, pathologists, botanists and horticulturalists have combined their efforts to find a solution for the problem. Progress has been made.

The purpose of the Michigan State College experiment is to evaluate some phases of published data in terms of the eastern climatic conditions, and set up a project to determine sucrose loss under a series of prescribed treatments which have some possibility of succeeding industrially.

The project consisted of a series of five forced-air treatments and three treatments using various rates of a chemical composed largely of sodium carbonate and a check.

## Description of Equipment

It was found that the J. I. Case experimental hay-curing barn could easily be adapted to such a project. This barn has 12- by 20-foot compartments which are protected with an aluminum roof. Three of the compartments were completely enclosed while the remainder had two sides open. The sugar beet storage project was carried on in the open compartments. It was hoped that this protection would eliminate one variable, namely that of beet absorption of solar energy. Building paper was used to seal the side walls against air leaks, and reduce thermo-conductivity from one treatment to another. However, it was found that the treatments in the bins exposed to the south sun were at a disadvantage due to the wall's being exposed to sun which made 1 to 2 degrees Fahrenheit difference in the diurnal temperatures of the beets 1 foot in from the wall.

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[2]The numbers in parentheses refer to literature cited.

The floors were made by heavy wire mesh laid over joists, making it possible to force air through the bins from the bottom.

Seven 6- by 10-foot bins were built into the compartments. Each bin was 8 feet deep and was large enough to carry approximately 10 tons of beets. Six of the bins were used for ventilation tests while the seventh was divided into three equal parts for chemical treatment of beets. A 1,000-c.f.m. fan was used at the end of a main tunnel with laterals feeding air to the respective bins. The air was metered to each bin at the main tunnel by small adjustable openings.

*Instruments for Recording Temperatures.*—Temperatures were taken by an electronic recording potentiometer and copper-constantan thermocouples. All thermocouples were calibrated to a mercury thermometer in stirred water bath prior to installing and were found to be correct to $\pm$ .4 degrees Fahrenheit. Temperatures were taken at eight points which were located as the beets were binned to give representative recordings throughout. At each point two thermocouples were installed; one in a beet and another recorded the air 6 inches away. This method of installation gave an opportunity to study temperature of the beets and of the air passing through the voids. A thermocouple was placed to record the air temperature as it entered the fan. The temperature of the air as it entered the beets was somewhat higher due to the heat generated by friction as it passed through the tunnel.

## Experiment Operations

*Weight Loss and Sugar Analysis Data.*—Freshly harvested beets were run over a Silver Roberts piler and weighed as they were binned. They were weighed again at the conclusion of the experiment. Each load was tared to determine actual usable beet tissue in the bins. All dirt lost in handling was recorded. Ten samples for sugar analysis were taken as beets were binned to secure a representative cross section of the beets for each treatment. Care was taken to select beets from the same areas as the bins were unloaded.

*Fan Operation.*—The fan was operated during the night hours and in one case it was operated when the temperature of the beets was higher than the air which could be forced through the beets.

*Temperature and Humidity Data.*—Air and beet temperatures and relative humidities were recorded at 6-hour intervals beginning at 6 p.m. of October 15. The quantities of air were calibrated with a velometer after the bins were filled. The water vapor in the air blown into beets has much to do with the keeping qualities. It is for that reason that relative humidity of the air entering the fan and the air leaving the bins was secured. The relative humidity data were secured by means of a sling-psychrometer. These data were obtained from the air as it entered the fan and as it left the beets.

**Treatments**

A. Check.—The bin used for this purpose was sealed with building paper over the wire-mesh floor. The purpose of this floor covering was to restrict natural thermo-siphoning of the air and tended to stabilize the temperature within the bin. It also gave the best possible check which would be congruent with the exploratory treatments.

B. The beets were wet down 5 days after binning. Ten cubic feet of air per minute per ton of beets were then forced through the beets for each successive night the fan was in operation. The quantity of water was not ascertained but enough was poured over the bin to run freely from the drain at the bottom. Wetting down was repeated on the seventh and ninth days of the experiment.

C. The beets in this treatment were subjected to 10 c.f.m. of air per ton of beets during the periods in which the fan was in operation.

D. No air was forced through the beets in this treatment until 5 days after they were binned. The purpose of this was to determine whether or not a bin of beets could be brought under control after respiratory action had passed through a number of cycles.

E. The beets were sprayed with water as they were binned. No measure was given water but there was no apparent excess after gravational waters had run free. The washing operation removed some dirt, the weight of which was accounted for by a tare figure. Ten cubic feet of air per ton per minute were forced through the beets during the period in which the fan was in operation.

F. This treatment is similar to treatment C except that the c.f.m. of air was increased from 10 to 20.

$G_1$ A chemical dust was used to coat the beets as they were loaded into the bins. This dust is composed of a compound which has growth inhibiting qualities and has been used with some degree of success in storage of small grains such as shelled corn, wheat, oats, barley and beans. It was felt that it might have some value in storage of sugar beets. The chemical analysis of this compound is:

$CaCO_3$—22.50 percent
$Na_2CO_3$— 9.03 percent
$NaHCO_3$—60.83 percent
$SiO_2$— .31 percent
$MgCO_3$— 5.75 percent or MgO—2.75 percent

Beets were treated with 1 pound of dust per ton.

$G_2$ Two pounds of the above chemical per ton of beets.

$G_3$ Five pounds of the above chemical per ton of beets.

## Discussion

The criteria for evaluating the results of this experiment is the number of pounds of sugar saved per ton of fresh beets. But, before studying these data, it is quite desirable that we first concern ourselves with those data secured, throughout the progress of the experiment—namely, temperatures and relative humidities. The treatments will be discussed in chronological order from the least to the most effective.

*Temperature and Humidity Data by Bins.* ($G_3$), ($G_2$), ($G_1$).—The average temperature of the beets in bins $G_1$ and $G_3$ followed somewhat the same curve as the outside air and tended toward the extremes of the second day (figure 1). The beets in $G_2$ followed the mean outside temperature of the second day. All three bins remained below the check bins' temperature, after the second day. These treatments were not at all effective inasmuch as they lost more sugar than the check and, therefore, do not warrant any further discussion at this time.

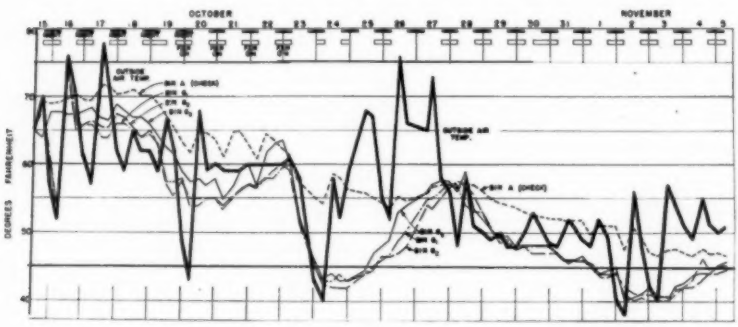


Figure 1.—Average bin temperatures for bins $G_1$, $G_2$, $G_3$. Beets were treated chemically as they were loaded into the bins.

D. You'll recall that in this treatment 10 c.f.m. of air were first blown into the beets 5 days after the beets were loaded into the bins.

The average temperature did not follow that of the check bin at the start (figure 2). This is ascribed to the fact that there was a 3-foot space below the beets tending to give a stabilized effect. The radiation of the earth below the bin cooled at least a portion of the beets. October 21 air was blown through the beets for the first time. Beet temperature dropped slightly below the check bin and finished the experiment somewhat higher. This is partly attributed to the fact that one wall was exposed to the south.

The relative humidity of the air entering the fan is plotted in the second graph (figure 2). As was expected, the peaks of this graph occur during the night. The third graph shows the pounds of water vapor which were retained or lost during the fan's operation. This broken curve can be correlated with the air temperature and the subsequent temperature of the beets.

It points out the tendency for the beets to take on water vapor after each time the bin temperatures dropped. In most cases the quantity of the water vapor was not lost or gained in proportion to the increase in volume of air.

B. The beets in this treatment were wet down on October 19 and 10 c.f.m. of air turned into them for the first time. This partly accounts for the rapid decrease in temperature (figure 3). The beet temperature again responded to a wetting down on October 20 when it dropped below the recorded night temperature. The relative humidity of the air above the bin was slightly higher than in the other treatments, after each wetting. No doubt greater cooling by evaporation might have been accomplished if air had been blown through during the daylight hours, when the relative humidity of the incoming air was low.

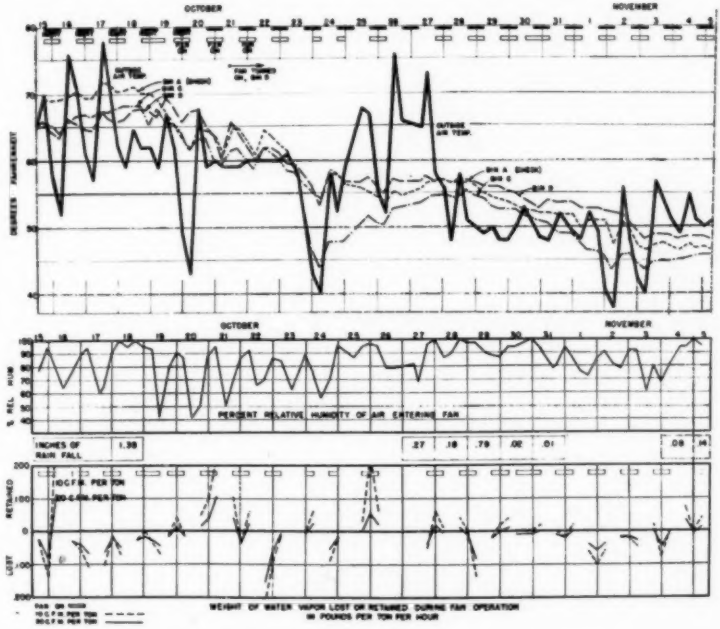


Figure 2.—Data pertaining to treatments A, C and D.

C. The beets in this treatment were given 10 c.f.m. of air per ton. The temperature of the beets was somewhat lower than the check bin at the start and dropped to 45 degrees Fahrenheit (figure 2) the night of October 23 and remained below that of the check to the conclusion of the experiment. Advance stages of decay localized about the thermocouples. The cool air blown into the bin was enough to limit the decay and permitted the "dead" beets to remain cool.

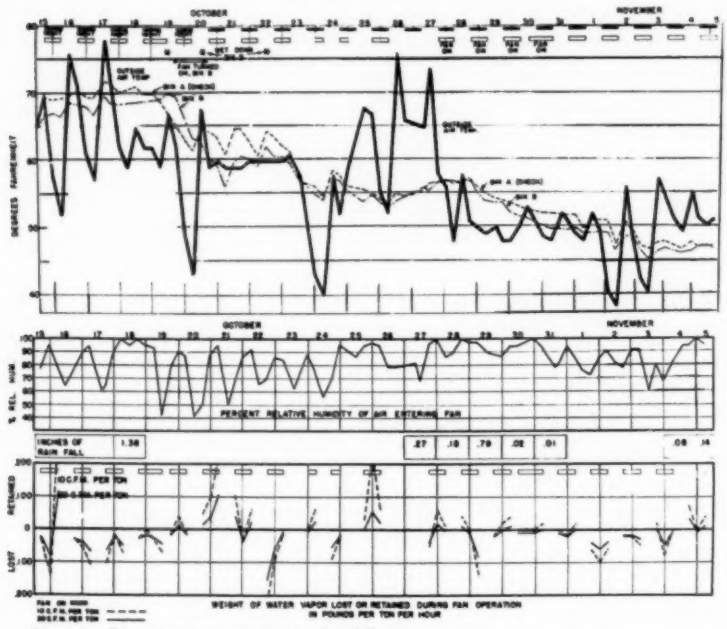


Figure 3.—Data pertaining to treatments A and B.

E. The beets in this treatment were sprayed with water as they were binned and subjected to 10 c.f.m. of air per ton. The sudden drop in the temperature is ascribed to the wetting (figure 4). This initial cooling held the bin in check until the second day when the excess water had been evaporated. It is believed that if the air volume had been doubled better results would have been accomplished.

F. This bin of beets was blown with 20 c.f.m. of air per ton Although they did not markedly respond to the increase air volume at first the bin temperature curve does dip during the night hours (figure 4). The temperature remained below that of the next most successful treatment, namely treatment E.

*Analysis of Final Results.*—A better understanding of condition of beets and a better evaluation of each method might be afforded by a thorough study of the following creptic summary. As was mentioned previously, the criteria for evaluating a method is the saving of sugar. The total weight loss is not proportional to sugar loss due to the decomposition of beet tissue.

The check treatment shall be considered first and the other treatments shall be again discussed in chronological order from the least to the most effective. (Figure 5.)

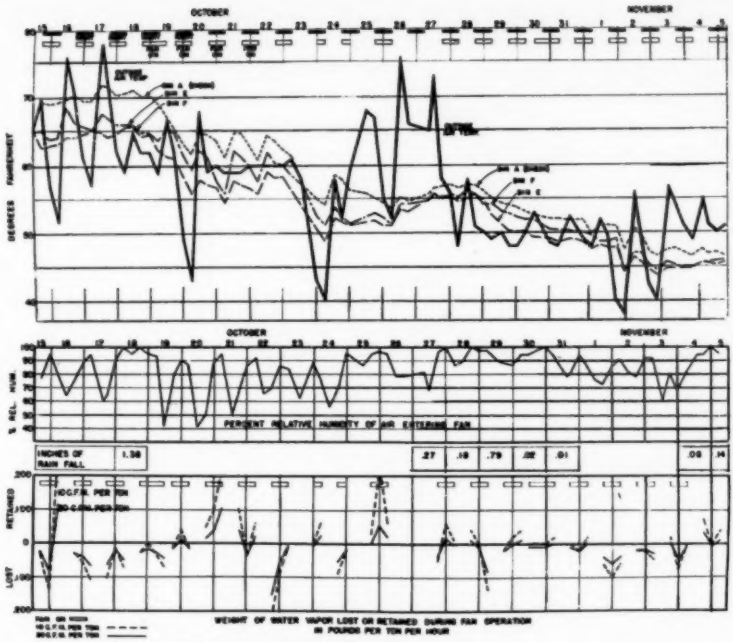


Figure 4.—Data pertaining to treatments A, E and F.

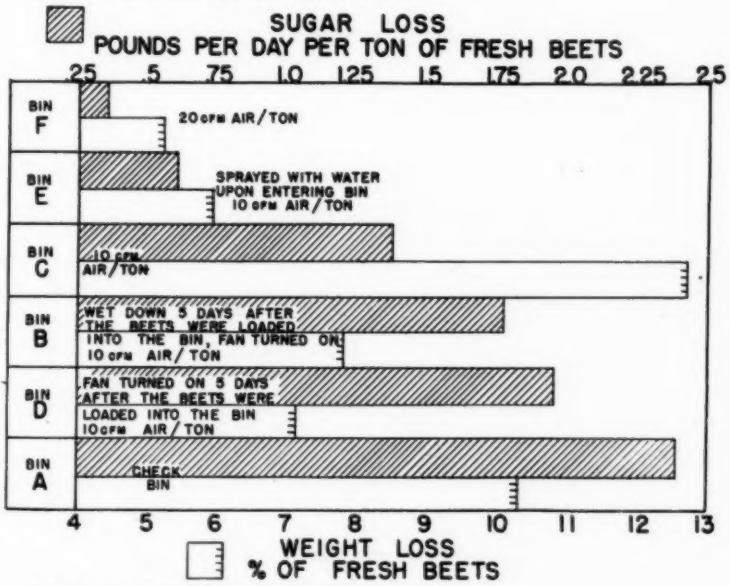


Figure 5.—Summary of the sugar and weight losses.

A. Check treatment in which beets were put into a bin with sides and bottom sealed.

Sugar lost—2.24 pounds per day per ton of beets.
Loss in weight of beets—10.3 percent.
Tare for bin—.6 percent.
Active leaf growth on crowns—.2 percent, localized on top layer.
Decay—2 percent, only isolated cases.
Mould growth—heavy.
Dehydration—noticeable on top-half.

($G_3$), ($G_2$), ($G_1$).—The beets in these three treatments were covered at the rates of 5 pounds, 2 pounds and 1 pound of chemical per ton, respectively.

Sugar lost—4.66, 4.11 and 2.60 pounds per day per ton of beets.
Loss in weight of beets—13.6, 8.5 and 11.6 percent respectively.
Tare for the bins—.6 percent.
Active leaf growth on crowns—none.
Decay—9, 5 and 1 percent respectively.
Dehydration—$G_2$ not to the extent of others.

D. The 10 c.f.m. of air per ton was not forced into bin until after heating had started. It was quite evident that the beets were not brought under control soon enough to make treatment effective.

Sugar lost—1.90 pounds per ton per day.
Loss in weight—7.1 percent.
Tare—.7 percent.
Active leaf growth on crowns—none.
Decay—1 percent.
Mould growth—about trash, heavy, extending to light at top and bottom.
Dehydration—1.3 percent.

B. Beets in this treatment were wet down 4 days after binning, as was mentioned previously and 10 c.f.m. of air per ton of beets were turned into them for the first time. This treatment was not too successful due to the fact that the beets had passed through one or two heat cycles. Tissue breakdown had no doubt taken place.

Sugar lost—1.7 pounds per ton per day.
Loss in weight—7.79 percent.
Tare—1 percent.
Active leaf growth on crowns—95 percent.
Decay—1.2 percent.
Mould growth—minimum about trash.
Dehydration—noticeable on top and bottom layers.

C. The beets in this treatment were blown with 10 c.f.m. per ton during night hours.

Sugar lost—1.32 pounds per ton per day.

Loss in weight—12.07 percent.

Tare—.8 percent.

Active leaf growth on crowns—30 percent.

Decay—.3 percent.

Mould—light mould prevailed throughout.

Dehydration—top and bottom layer.

E. The beets in this treatment were sprayed with water as they were being binned and blown with 10 c.f.m. of air per ton during night hours. Treatment quite successful.

Sugar loss—.57 pound per ton per day.

Weight loss—5.89 percent.

Tare—.5 percent.

Active leaf growth on crowns—50 percent.

Mould—very light—freshness nearly equal as to when they were binned.

Dehydration—merely noticeable.

F. The beets in this treatment were blown with 20 c.f.m. of air per ton during night hours. The treatment was most successful.

Sugar loss—.33 pound per ton per day.

Weight loss—5.2 percent.

Tare—.7 percent.

Leaf growth—none.

Decay—none.

Mould—very slight.

### Conclusions and Recommendations

1. Means must be found to remove more of the trash before the beets are stockpiled. Decay and mould always starts in the trash where air could not penetrate.

2. Stock piles should have 20 to 30 c.f.m. air forced through them during night hours until the temperature drops—5 to 10 c.f.m. would then be sufficient to hold them. This recommendation has been given by Brooks and Bainer (2).

3. Limited wetting of beets as they are stockpiled indicates that it will be a successful method of controlling temperatures if enough air could be forced into the pile to cause sufficient evaporation. Beets which are too moist will grow readily in warm temperatures.

4. A severely injured and improperly topped beet does not keep well. The harvester must be in best possible adjustment.

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# Comparative Composition of Different Parts of the Sugar Beet Root[1]

C. A. Fort[2] and Myron Stout[3]

A few studies of the composition of different parts of the sugar beet root have been reported in European literature, but there have been none on beets grown in this country. Doubtless many experiments have been made with the object of determining the optimum topping level, but there is no evidence of more comprehensive studies. The work to be presented in this report was carried out in 1943-44 and developed out of the difficulties being experienced in obtaining truly representative pulp samples from stored beets. It was observed that when rasping sugar beet roots that were even slightly withered, the composition of the pulp collected on the shield differed from that of the pulp which accumulated on the beets along the edge of the rasped segments.

The published analyses of Von Floderer and Herke (1) in 1911 and of Von Urban (2) in 1907 primarily show the composition of cross sections of the sugar beet root beginning with the crown and ending with the tail section. It is evident from their data that the sugar concentrations tend to follow the contour of the beet. That is, the sugar concentration is lowest at the crown and at the end of the root. Beginning at the crown, it increases quickly to the maximum value about where the beet reaches its maximum diameter. From there on the sugar concentration decreases very slowly as the beet tapers down to the small tap root. Von Floderer and Herke also made some longitudinal sections as subdivisions of the cross sections, but the sectioning used indicated only small differences in composition between the central and outer portions.

In the present sectioning experiments longitudinal segments were taken of sugar beet roots topped as for commercial utilization with the object of learning the composition of the different layers proceeding from the outside to the center of the beet. The work also included sectioning of the crown portions so these data are also presented.

When a trimmed but untopped beet is split in half it is observed that the separation between crown tissue and the body tissue of the beet is quite definitely accomplished by a cut just slightly below the bottom leaf scar. The crowns were removed at this point and the outside 1/8 inch pared off. The crown tissue was divided into two parts, a top part and a bottom part. The point of division roughly corresponded to the bottom green leaf. In the case of the body of the beet it too was pared by removing the outside 1/8 inch. The tail portion was then removed roughly where the diameter was 1 inch.

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The main body of the beet was then sectioned lengthwise. The core or heart was removed by using a curved knife. It was about 1 inch in diameter at the top and tapered to a very thin piece at the bottom. Still using the curved knife, an additional sample was cut about ½ inch thick at the top, but tapered toward the bottom, and represented the material next to the core. The remainder of the body of the beet, which still amounted to half the total beet weight, was taken as the final sample. In two of the experiments eight beets each were used and the corresponding samples composited. In the third experiment only one beet was used. All beets weighed about 2½ pounds each and were thoroughly washed and the surfaces dried before sampling. Figure 1 shows the scheme of sectioning used and table 1 gives the composite results on the composition of the segments and the calculated compositions of the commercial beet, of the crown, and of the whole beet. All analytical results are given as percentages on beet tissue unless otherwise indicated.

Although it is recognized that similar sectioning of other beets from different fields, areas, and seasons may yield greater or smaller differences between segments, it is felt that these data indicate two general situations that are probably characteristic. First, there is the relatively low sucrose of the core portion of the beet with the sucrose increasing to its highest value in the outside 2/3 of the beet but dropping to a low value in the outer ⅛ inch. It is certain that in sampling beets for analysis the segment cut or rasped must remove the proper proportion of all layers in the depth of the beet toward the center as well as of the entire length of the beet. Even on fresh beets careless rasping, which does not cut to the true center or cuts deeper than the center, will lead to analyses which do not correctly represent the beet composition.

When dealing with beets that have lost moisture, as in storage or even during transportation or in the windrow, there is a tendency for some segregation of material from the different layers of the beet even if the rasping is done properly. It appears that the central portion of the beet which is lower in sucrose and higher in moisture is rasped by the outer edge of the rasp and rather completely thrown against the sample shield. The outer portions of the beet are to a considerable extent rasped by the sides of the rasp. Since this part of the beet is lower in moisture and relatively higher in sugar (in spite of the outer rind portion), and is also higher in marc (due to this rind portion), it is not completely thrown to the shield but is partly rolled over onto the beet along the edges of the cut. The more withered the beet, the more pronounced is this trend. This leads to a low sucrose result if the test is made on the pulp caught by the shield. This situation is of especial importance in beet-storage studies, and it has been necessary to adopt a procedure in which the proper segment is cut out of the beet by a special knife and the combined segments of a sample disintegrated in a mill to prepare a pulp for analysis.

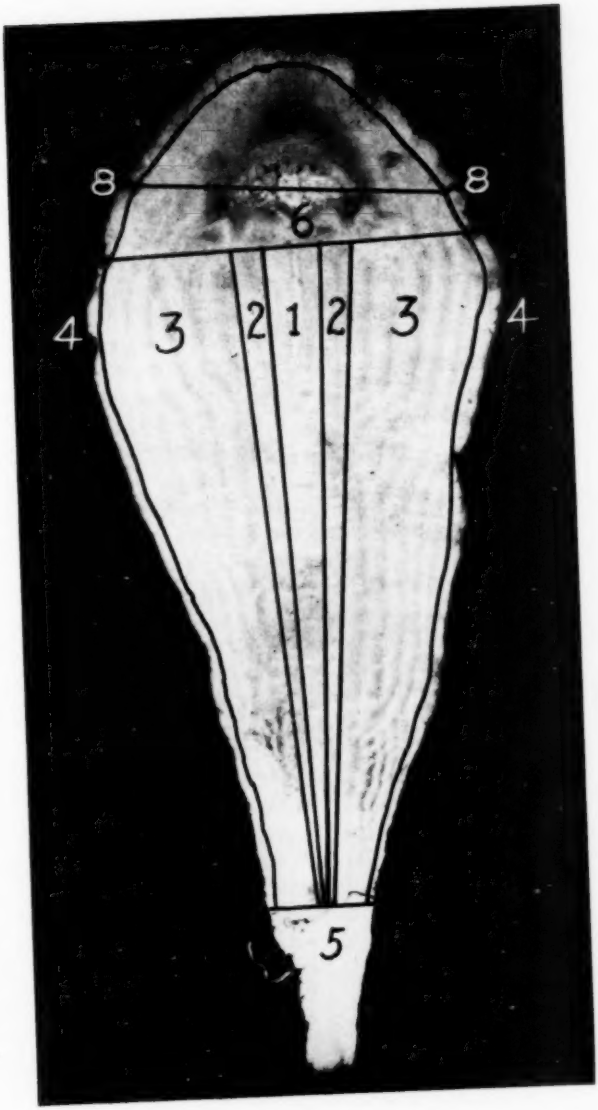


Figure 1.—Diagram of sectioning used.

Table 1.—Comparative composition of different parts of a sugar beet root.

| | Commercially topped beet | | | | | | Crown section | | | | Whole trimmed beet |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Core | Next core | Main body | Paring | Tail | Whole | Paring | Top tissue | Bottom tissue | Whole | |
| **Section number** | 1 | 2 | 3 | 4 | 5 | 1-5 | 8 | 7 | 6 | 6-8 | 1-8 |
| Weight, percentage part of beet | 14.6 | 16.1 | 52.7 | 13.0 | 3.6 | 100 | 33.0 | 38.5 | 28.5 | 100 | -- |
| Weight, percentage whole root | 12.7 | 14.0 | 45.9 | 11.3 | 3.1 | 87.0 | 4.3 | 5.0 | 3.7 | 13.0 | 100 |
| Direct polarization | 14.4 | 14.8 | 15.5 | 13.5 | 13.8 | 14.9 | 11.7 | 14.0 | 15.0 | 13.5 | 14.7 |
| True sucrose,* percentage | 13.7 | 14.2 | 14.9 | 13.0 | 13.4 | 14.3 | 11.1 | 13.3 | 14.4 | 12.9 | 14.1 |
| Reducing sugars, percentage | 0.12 | 0.12 | 0.13 | 0.28 | 0.13 | 0.15 | 0.24 | 0.16 | 0.14 | 0.18 | 0.15 |
| Raffinose,* percentage | 0.36 | 0.21 | 0.24 | 0.15 | 0.06 | 0.23 | 0.13 | 0.23 | 0.13 | 0.17 | 0.22 |
| Total sugars, percentage | 14.18 | 14.53 | 15.27 | 13.43 | 13.59 | 14.68 | 11.47 | 13.69 | 14.67 | 13.25 | 14.47 |
| Total dry solids, percentage | 21.3 | 21.7 | 22.2 | 23.5 | 22.0 | 22.1 | 23.8 | 22.4 | 22.6 | 22.9 | 22.2 |
| Mare(non-diffusables), percentage | 3.9 | 4.2 | 4.5 | 6.4 | 5.2 | 4.6 | 7.7 | 5.4 | 5.1 | 6.0 | 4.8 |
| Juice dry solids, percentage | 17.4 | 17.5 | 17.7 | 17.1 | 16.8 | 17.5 | 16.1 | 17.0 | 17.5 | 16.9 | 17.4 |
| Cold diffusion juice | | | | | | | | | | | |
| Sulphated ash, percentage | 1.35 | 1.25 | 0.95 | 1.40 | 1.25 | 1.13 | 1.58 | 1.13 | 1.03 | 1.25 | 1.15 |
| Organic non-sugars | 1.87 | 1.72 | 1.48 | 2.27 | 1.96 | 1.69 | 3.05 | 2.18 | 1.80 | 2.40 | 1.78 |
| Total nitrogen X 6.25, percentage | 1.20 | 1.15 | 1.04 | 1.78 | 1.44 | 1.19 | 1.73 | 2.03 | 1.28 | 1.72 | 1.26 |
| Non-protein N X 6.25, percentage | 0.36 | 0.34 | 0.39 | 0.91 | 0.59 | 0.45 | 0.81 | 0.87 | 0.49 | 0.74 | 0.49 |
| On juice dry solids basis | | | | | | | | | | | |
| Polarization purity | 82.7 | 84.6 | 87.6 | 78.9 | 82.1 | 85.1 | 72.7 | 82.3 | 85.7 | 79.9 | 84.5 |
| True sucrose purity | 78.7 | 81.1 | 84.2 | 76.0 | 79.8 | 81.7 | 68.9 | 78.2 | 82.3 | 76.3 | 81.0 |
| Reducing sugars, percentage | 0.69 | 0.68 | 0.73 | 1.64 | 0.77 | 0.86 | 1.49 | 0.94 | 0.80 | 1.07 | 0.86 |
| Sulphated ash, percentage | 7.8 | 7.1 | 5.4 | 8.2 | 7.4 | 6.5 | 9.8 | 6.6 | 5.9 | 7.4 | 6.6 |
| Organic non-sugars, percentage | 10.7 | 9.8 | 8.4 | 13.3 | 11.7 | 9.7 | 18.9 | 12.8 | 10.3 | 14.2 | 10.2 |

Note: All values on beet tissue basis except in bottom section of table.
*True sucrose and raffinose determined by double enzyme method.

The second characteristic to which attention will be called is the relatively high sucrose percentage of the crown portion of the beet once the crown is pared thus removing the petiole stubs, scar tissue, and rind. In the beets used in this study the petioles had been previously trimmed close to the skin, hence the very low test of the crown parings still is not low as it would be if longer petiole stubs had been present. In both the crown and the body of the beet the highest concentrations of reducing sugars and of organic non-sugars and minerals occur in the parings.

The variation that may occur between experiments on sectioning beets (including comparisons of crowns and commercial beets) is well demonstrated in the case of two of the experiments of this study which compared beets from high- and low-fertility levels in the same test field and using the same variety. The difference in fertility level was due to the fact that the one plot was not manured while the other received an especially heavy application of chicken manure. The comparison of results is given in table 2. Eight beets of similar size (about 2½ pounds each) were used in each experiment.

This comparison of high- and low-fertility beets indicates that the contrasts between different segments are much greater in the low-fertility, high-sucrose beet. In the first place the proportional amount of crown tissue was smaller for the low-fertility beet even as the leaf growth probably was less. It should be recalled that the beets were topped, after they were split, near the line separating the crown tissue from the remainder of the root. This seemed to correspond to low field topping. The sucrose in the commercial beet from the high-fertility plot was numerically higher than that of the total crown by only 0.9 percent and the purity difference was 4.1. In the low-fertility beet the differences were 3.5 percent for sucrose and 10.5 in purity. This was true in spite of the fact that the crown of the low-fertility beet was of fair quality. Thus, from the viewpoint of untopped whole beets, the inclusion of the crown is not too serious in the low-sucrose, high-fertility beets, although it dropped the sucrose reading 0.2 percent and the juice purity 0.9 percent below the readings for the commercial beet. For the low-fertility beet the respective differences were 0.4 percent sucrose and 1.1 percent in purity. The low-fertility beet represents the usual field condition and the high-fertility level used here is an unusual situation.

The comparative values for non-sugars are not as was expected because the low-fertility beets show approximately as high mineral and organic non-sugar concentrations as the high-fertility beets. On the solids basis, due to the greater storage of sugars in the low-fertility beets, the non-sugar percentages are lowest in the low-fertility beets. The total nitrogen concentration is the same at both fertility levels in the commercial or the whole beets, but the crowns of the low-fertility beets were higher in nitrogen than the crowns of the high-fertility beet. The reverse was true for the body of the beets.

**Table 2.**—Comparative composition of sectioned beets from high- and low-fertility plots.

| | Beets from high-fertility plots | | | | | Beets from low-fertility plots | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (W) Whole trimmed beet | (C) Crown section | (T) Topped beet | Numerical differences | | (W) Whole trimmed beet | (C) Crown section | (T) Topped beet | Numerical differences | |
| | | | | T-W | T-C | | | | T-W | T-C |
| Weight, percentage of whole root | 100 | 15.2 | 84.8 | -- | -- | 100 | 11.2 | 88.8 | -- | -- |
| **Pulp analysis** | | | | | | | | | | |
| Total dry solids, percentage | 18.6 | 19.3 | 18.4 | —0.2 | —0.9 | 25.3 | 25.7 | 25.1 | —0.2 | —0.6 |
| Water, percentage | 82.4 | 80.7 | 81.6 | +0.2 | +0.9 | 74.7 | 74.3 | 74.9 | +0.2 | +0.6 |
| Marc (non-diffusable), percentage | 4.0 | 5.0 | 3.7 | —0.3 | —1.3 | 4.7 | 6.6 | 4.3 | —0.4 | —2.3 |
| **Diffusion juice (cold)** | | | | | | | | | | |
| Dry solids, percentage beet | 14.6 | 14.3 | 14.7 | +0.1 | +0.4 | 20.6 | 19.1 | 20.8 | +0.2 | +1.7 |
| Direct polarization | 12.3 | 11.4 | 12.5 | +0.1 | +1.1 | 18.1 | 15.1 | 18.5 | +0.4 | +3.4 |
| True sucrose, percentage beet | 11.6 | 10.9 | 11.8 | +0.2 | +0.9 | 17.8 | 14.7 | 18.2 | +0.4 | +3.5 |
| Reducing sugars, percentage beet | 0.09 | 0.12 | 0.08 | —0.01 | —0.04 | 0.17 | 0.21 | 0.16 | —0.01 | —0.05 |
| Sulphated ash, percentage beet | 1.20 | 1.29 | 1.18 | —0.02 | —0.11 | 1.01 | 1.30 | 0.97 | —0.04 | —0.33 |
| Organic non-sugars, percentage beet | 1.43 | 1.76 | 1.35 | —0.08 | —0.41 | 1.48 | 2.75 | 1.32 | —0.16 | —1.43 |
| Total nitrogen X 6.25 percentage beet | 0.88 | 1.25 | 0.81 | —0.07 | —0.44 | 0.88 | 1.51 | 0.80 | —0.08 | —0.71 |
| Non-protein N X 6.25, percentage beet | 0.52 | 0.74 | 0.48 | —0.04 | —0.26 | 0.59 | 0.99 | 0.54 | —0.05 | —0.45 |
| **On dry solids basis** | | | | | | | | | | |
| Purity (true sucrose) | 79.4 | 76.2 | 80.3 | +0.9 | +4.1 | 86.4 | 77.0 | 87.5 | +1.1 | +10.5 |
| Reducing sugars, percentage solids | 0.62 | 0.84 | 0.54 | —0.08 | —0.30 | 0.78 | 1.10 | 0.77 | —0.01 | — 0.33 |
| Sulphated ash, percentage solids | 8.22 | 9.0 | 8.0 | —0.2 | —1.0 | 4.90 | 6.8 | 4.7 | —0.2 | — 2.1 |
| Organic non-sugars, percentage solids | 9.8 | 12.3 | 9.2 | —0.6 | —3.1 | 7.2 | 14.4 | 6.3 | —0.9 | — 8.1 |

Note: The difference in fertility level consisted of an extra heavy application of chicken manure as contrasted with no manure. The tonnage of topped beets compared as 22 tons to 16 tons per acre, respectively. By calculation the untopped beet tonnages would have been 26 tons and 18 tons, respectively.

In the experiments discussed above analyses of the ash constituents were not made, but in an earlier experiment they were. These supplemental tests are given in table 3.

**Table 3.—Distribution of non-sugars in a sugar beet root.**

| | | Commercially topped beet | | | |
|---|---|---|---|---|---|
| | Crown | Core | Next core | Main body | Paring |
| Weight distribution, percentage | 11.4 | 22.7 | 31.8 | 22.7 | 11.4 |
| Total dry solids, percentage | 23.41 | 20.63 | 21.12 | 22.83 | 23.20 |
| Diffusion juice dry solids, percentage | 17.14 | 16.33 | 16.90 | 17.05 | 15.81 |
| Marc (non-diffusable dry solids) percentage | 6.27 | 4.30 | 4.22 | 5.78 | 7.39 |
| True sucrose, percentage | 12.8 | 12.2 | 13.9 | 14.6 | 11.7 |
| True juice purity, percentage | 74.9 | 74.9 | 82.2 | 85.4 | 74.1 |
| Carbonate ash, total in pulp, percentage | 1.17 | 1.23 | 1.12 | 0.90 | 1.48 |
| Carbonate ash, diffusable, percentage | 0.90 | 1.06 | 0.97 | 0.65 | 1.06 |
| Carbonate ash, non-diffusable, percentage | 0.27 | 0.17 | 0.15 | 0.25 | 0.42 |
| Sulphated ash, total in pulp, percentage | 1.51 | 1.57 | 1.49 | 1.19 | 1.97 |
| Sulphated ash, diffusable, percentage | 1.12 | 1.48 | 1.33 | 0.85 | 1.44 |
| Sulphated ash, non-diffusable, percentage | 0.39 | 0.09 | 0.16 | 0.34 | 0.53 |
| Silica ($SiO_2$) in pulp, percentage | 0.009 | 0.003 | 0.005 | 0.022 | 0.081 |
| Silica, diffusable, percentage | 0.006 | 0.000 | 0.000 | 0.008 | 0.007 |
| Silica, non-diffusable, percentage | 0.003 | 0.003 | 0.005 | 0.014 | 0.074 |
| Chloride, diffusable, (Cl), percentage | 0.161 | 0.205 | 0.171 | 0.100 | 0.019 |
| Sulphate, diffusable, ($SO_3$), percentage | 0.032 | 0.029 | 0.042 | 0.020 | 0.037 |
| Phosphate, diffusable, ($P_2O_5$), percentage | 0.061 | 0.076 | 0.067 | 0.045 | 0.100 |
| Organic acid radical,* percentage | 0.434 | 0.626 | 0.486 | 0.384 | 0.748 |
| Organic non-sugars, diffusable, percentage | 2.64 | 2.18 | 2.20 | 2.12 | 2.96 |
| Total nitrogen X 6.25, pulp, percentage | 2.81 | 2.12 | 2.51 | 2.28 | 3.24 |
| Nonprotein N X 6.25, diffusable, percentage | 1.01 | 1.33 | 1.38 | 1.04 | 1.26 |
| Amino nitrogen X 10.5,** percentage | 0.34 | 0.75 | 0.77 | 0.51 | 0.56 |
| pH of normal diffusate | 6.8 | 6.4 | 6.6 | 6.8 | 6.8 |

Note: All data given as percentage on beet tissue unless otherwise indicated. The diffusions were made at room temperature.

*Organic acids calculated from true ash alkalinity and an assumed combining weight of 80 for the acid.

**Amino nitrogen determined by colorimetric copper nitrate method and expressed as glutamic acid.

In the main, the ash constituents follow the trends shown by the total ash. The chloride content was determined direct on juice but sulphate and phosphate were determined on the carbonate ashes. The organic acid radical is a calculated value based on true ash alkalinities. In general, it is highest where the mineral acid radicals are lowest in concentration. The differences between the total ash in pulp and the diffusable ash shows that a fair proportion of total ash is not diffusable. This material is not primarily silica, as might be supposed, because the silica determined is a very small part of the total non-diffusable ash with the exception of the paring where the silica does account for 19 percent of the insoluble ash. This value possibly indicates the slight contamination with soil that still remained after washing the beets.

Total nitrogen was greatest in the crown and paring but non-protein nitrogen (the part not coagulable by acetic acid and boiling) was highest in the central portions of the body of the beet. In other words, a much larger proportion of the nitrogen in the crown and paring was protein. The amino acid content, as indicated by the colorimetric copper nitrate method,

was in agreement with the trends shown by concentrations of non-protein nitrogen.

A final observation can be made concerning the reducing sugar content in beets, namely that there is a possibility that storage, where spoilage is not a factor, increases the content of these sugars in the crown more rapidly than in the beet proper. As these sectioning tests were incidental to the regular program of work they were in part made after storage in a moist root cellar at about 40 to 45 degrees Fahrenheit. The one experiment made on fresh beets showed 0.12 percent reducing sugars in the crown against 0.09 percent in the commercial beet. Another experiment made after 30 days in storage showed corresponding values of 0 21 percent and 0.15 percent reducing sugars. In the case of an experiment made after 80 days' storage, 0.35 percent and 0.15 percent of reducing sugars were found in the crown and commercial beets, respectively. These results are tentative as the experiments were not planned for study of this kind. Under some storage conditions, topped beets show more susceptibility to spoilage by micro-organisms and are higher in reducing sugars than corresponding untopped beets.

## Summary

1. The core of the sugar beet root analyses much lower in sugars and higher in minerals than the main body of the root. From the core outward sucrose percentage increases to a maximum and then sharply drops at the outside 1/8-inch rind layer.

2. It is pointed out that this variation in composition may have a decided effect on analytical results unless care is taken that the rasping of pulp is correctly performed.

3. Analyses made of crowns and topped-root portions of the beets from plots of low- and high-fertility levels indicate that beets low in sucrose because of over-fertilization have sucrose and purity values for the crowns and for the corresponding commercial beets that are not very different, but in high-sucrose beets from fields of normal values for fertility there are large differences in sucrose and purity between these portions of the root.

4. The mineral and nitrogen concentrations in beets from high-fertility plots were lower than in the beets from low-fertility plots, but the reverse is true on the solids basis.

5. Mineral constituents such as chlorides, sulphates, and phosphates follow the general trends indicated by total ash.

6. It is possible that in the storage of trimmed but untopped beets there is a more rapid increase in reducing sugars in the crown tissue than in the body of the sound beet.

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# Sugar Beet Storage Experiment, 1947

A. R. Downie[1]

A substantial saving in sugar was obtained by blowing cold night air through a beet storage pile at Rocky Ford, Colorado, in the fall of 1946. The sugar loss in the ventilated pile was 0.3 pound per day per ton of beets stored, while the loss in the non-ventilated pile was 0.5 pound per day per ton of beets stored. This difference was obtained under ideal beet-storage conditions and for a storage period of only 20 days.

In view of the results obtained in 1946, another test was conducted in the fall of 1947 at Rocky Ford, Colorado.

## Experimental Procedure

Two storage piles were made, one of 1,178 tons and one of 1,128 tons. Five wooden ducts placed at right angles to the pile were spaced at 12-foot intervals under the 1,178-ton pile, as it was being made. These ducts were made with 3- by 12-inch sides, spaced 19 inches apart. They were strengthened crosswise at 4-foot intervals with pieces of 2- by 4-inch lumber on top and bottom. Two 3- by 12-inch planks were then nailed on top, leaving a 1-inch space between. This construction left a 1-inch space along the middle of the top of the duct and a 2-inch gap along the sides where the 3- by 12-inch planks rested on the 2- by 4-inch braces. The ducts were made up in 10-foot lengths to facilitate handling. The 10-foot lengths were fitted together as the piling progressed.

In placing the ducts under the pile, one end of each duct projected 2 feet beyond the side of the beet pile. This end of the duct was covered with a filter cloth for a distance of 8 feet into the pile to prevent escape of air before reaching a distance into the pile. The other end of each duct was closed and blanked off, and came to within 8 to 10 feet of the opposite side of the pile.

A fan, with a capacity of 2,400 cubic feet of air per minute, was placed in the projecting ends of each of the five ducts. When all five fans were operating, this made a total capacity of 10 cubic feet of air per ton of beets stored.

During the process of making the two piles, captive samples 20 beets each, enclosed in wide-mesh fiber sacks, were placed at different levels in each of the two piles. There were 45 of these captive samples placed in each pile. These samples were selected as follows: A sufficient quantity of beets was taken from each truck-load to make up two 20-beet samples. The beets for each of the 20-beet samples were selected in pairs as nearly equal in size, shape, type of topping, etc., as possible. One beet from each pair went into one 20-beet sample, and the other beet into the second 20-beet sample.

[1]A. R. Downie, Plant Pathologist, Rocky Ford, Colorado.

One of the 20-beet samples was placed in a water-proofed sampling bag, taken to the laboratory, divided into two 10-beet samples, and analyzed for sucrose, within a period of 24 hours. The beets in the duplicate 20-beet sample were numbered, weighed individually, placed in a wide-mesh fiber sack and placed in the pile as soon as possible.

Temperatures of the beet piles were obtained by hanging stem thermometers inside ½-inch pipe which had been driven into the beet piles at different levels. Six thermometers with rubber tubing over both ends were suspended 6 feet below the surface of each pile and six thermometers were suspended at the 12-foot level below the surface of each pile. Readings were made three times (8:00 a.m., 1:00 p.m., and 5:00 p.m.) a day for the first 2 weeks but only twice (8:00 a.m. and 5:00 p.m.) for the remainder of the storage period.

As soon as the experimental pile was completed, the top, the south end, and the west side were covered with a lime slurry in order to reflect the sun's rays. The fans were turned on the same night. The fans were operated from 9:00 p.m. to 6:00 a.m. when temperatures were suitable.

The two piles, one with ducts referred to as the experimental pile, and one piled in the regular manner referred to as the check pile, were in storage for a period of 40 days.

## Results

The initial temperature of the beets going into the experimental pile was approximately 63 degrees Fahrenheit, while the temperature of the beets going into the check pile was 56 degrees Fahrenheit. Due to a drop in air temperature, all of the beets in the check pile, except approximately 80 tons, went in fairly cool.

A hot spot started to develop on the end of the check pile 5 days after the pile had been completed. The temperatures in this spot continued to go up and by the tenth day of storage the thermometers registered up to 88 degrees Fahrenheit. Approximately 240 tons of beets were removed and processed in order to save them. At least 5 to 7 tons of beets removed at this time were badly decayed. One of the samples which happened to be in the center of this spot was analyzed for sucrose and was found to have a reading of 1.15 percent. The duplicate sample which was analyzed at the time of piling tested 16.55 percent sucrose.

## Temperatures

The average temperatures for the two piles and the average daily mean are presented graphically in figure 1.

The average temperature for the experimental pile for the last 35 days of storage was 38.4 degrees Fahrenheit, while the corresponding figure for the check pile was 50.2 degrees Fahrenheit. This makes an average temperature differential of 11.8 degrees Fahrenheit between the two piles.

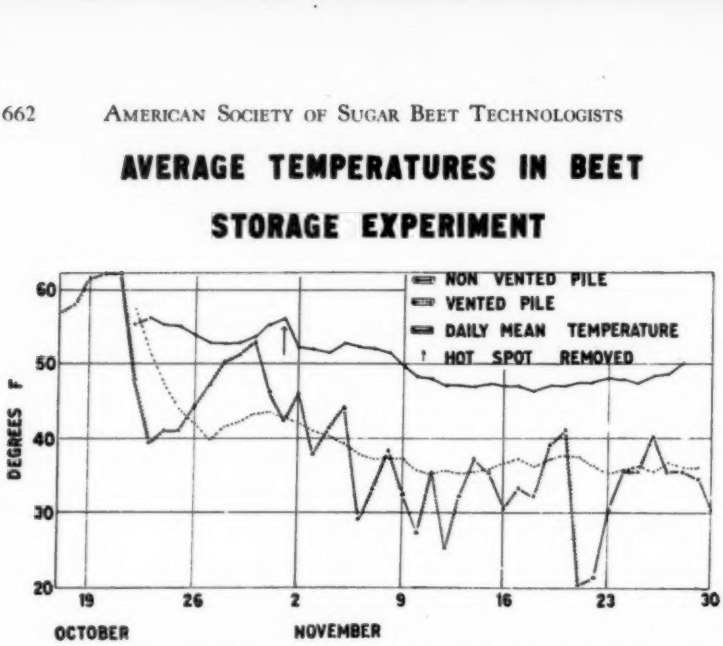



Figure 1.—By use of forced ventilation, the temperature of the experimental pile was reduced from around 58 degrees Fahrenheit to 40 degrees Fahrenheit in the first 6 days of storage, while the average temperature of the check pile was 54 degrees Fahrenheit. Although temperatures were taken at 6- and 12-foot levels below the surface of the two piles, for summarization purposes the readings for the two different levels were averaged for each pile. During the period of storage the relationship between temperatures at 6 and 12 feet below the surface of the experimental pile was fairly constant. The temperature at the 12-foot level was approximately 4 degrees Fahrenheit cooler than at the 6-foot level. This relationship was not nearly as constant in the check pile, due in most cases to small centers of mold which developed at the different depths.

### Losses from Shrinkage

A total of 43 of the special samples were recovered from the experimental pile. The total weight of these samples before they were placed in the pile was 1,624.7 pounds. The weight after being in storage 40 days was 1,576.9 pounds. This represents a shrinkage in weight of 2.94 percent.

Forty-three of the original 45 samples in the check pile were also recovered. The original weight on these samples was 1,574.99 pounds, while the weight on recovery from the pile was 1,429.20 pounds, or a shrinkage in weight of 9.26 percent for the 40-day storage period.

### Sugar Losses

The average sucrose for the duplicate samples for the experimental pile which were analyzed at the time of piling, was 16.76 percent. The average sucrose of the 43 samples recovered from the experimental pile was 17.13 percent. This represents a gain in sugar percentage of 0.37 percent.

The average sucrose of the 43 duplicate samples for the check pile, which were analyzed at the time of piling, was 16.75 percent. The average

sucrose of the 43 samples recovered from the check pile after 40 days of storage was 15.14 percent. This represents a loss in sugar percentage of 1.61 percent.

## Shrinkage and Sugar Losses

The shrinkage loss and the loss in sucrose, as well as the losses of sucrose per ton per day of storage, are presented in table 1.

**Table 1.**—Comparative results of beets stored in experimental pile and in check pile.

| | Experimental Pile | | | Check Pile | | |
|---|---|---|---|---|---|---|
| | Initial | End of storage | Loss or gain | Initial | End of storage | Loss or gain |
| Total weight of samples (lbs.) | 1624.71 | 1576.92 | —2.94% | 1574.99 | 1429.20 | —9.26% |
| Average percent sucrose | 16.76 | 17.13 | +0.37 | 16.75 | 15.14 | —1.61 |
| Pounds sugar per ton of beets | 335.2 | 330.3 | —4.9 | 335.0 | 274.76 | —60.24 |
| Loss of sugar per ton per day stored (lbs.) | | | —0.122 | | | —1.505 |

By calculating losses on a tonnage basis, it is found that the loss of sugar per ton per day of storage was 0.122 pound in the experimental pile, as compared to a loss of 1.505 pounds sugar per ton per day of storage in the check pile.

## Discussion

The loss of 1.505 pounds sugar per ton per day of storage in the check pile appears to be high for the temperature differential that was maintained between the two piles. However, spoilage of beets, due to micro-organisms, influenced sugar losses. Individual beets, in samples taken from the check pile, showed lesions which quite often penetrated to the heart of the beet. Also, there were some samples which showed rot on all 20 of the beets in the sample.

The only places in the experimental pile where mold was present was on the tip ends of the beets. This was due, to a large extent, to partial wilting of the beets due to the high temperatures occurring at the time of piling. There was also some mold in the experimental pile caused by packing of beets in the paths followed by the experimentalist when temperature readings were secured. Laying planks between the temperature stations would probably eliminate some of the damage due to this cause.

Observations on the check pile and on other beet piles indicate that beets going into piles in a wilted condition are one of the chief focal points for the development of micro-organisms and the subsequent development of hot spots. Although many of the beets going into the experimental pile were more or less wilted, the fairly rapid drop in temperature made conditions quite unfavorable for the development of the micro-organisms. However, even where forced ventilation is practiced, it would be much more advantageous to process wilted beets immediately rather than storing

them. There is always the danger that night temperatures may not be low enough to cool the pile to temperatures unfavorable for moderate growth of molds and bacteria.

There is no doubt that if night temperatures are low enough, forced ventilation of beet piles will result in substantial reduction in sugar loss in the average storage season. In seasons unfavorable to beet storage, such as the high temperatures experienced in the 1947 season, the reduction in sugar loss in beets under controlled storage will be sufficient to make a substantial return on the investment required for controlled storage equipment.

## Summary

The temperature in a 1,178-ton pile of sugar beets was lowered from 58 degrees Fahrenheit to 40 degrees Fahrenheit in 6 days by the use of forced ventilation with cool night air. The average temperature maintained in this pile was 38.4 degrees Fahrenheit as compared to 50.2 degrees Fahrenheit for a non-ventilated pile.

Losses due to shrinkage in weight were 2.94 percent in the experimental pile, as compared to 9.26 percent in the check pile.

Samples placed in the experimental pile lost 0.122 pound of sugar per ton per day stored, while the samples in the check pile lost 1.505 pounds sugar per ton per day of storage.

# Permanent Beet Storage Installation Cost Studies

G. W. HOWARD[1]

FOR SEVERAL YEARS we have been making experiments on the storage of sugar beets in regard to air capacity, friction loss, cooling efficiency, evaporative cooling, freezing temperatures, air washing and relative humidity. These problems all have to be approached from a scientific and experimental angle and their results are very much necessary before we can proceed in any kind of commercial storage installation. However, in the meantime, we can make tentative plans on paper for the purpose of estimating what our beet storage costs will be for any one of a number of varying conditions. The purpose of this paper is to estimate as nearly as possible the cost of storing sugar beets on a 10,000-ton scope with a permanent installation considering such variables as 1. open pile versus completely controlled closed piles; 2. 20 c.f.m. air requirement against 15 and 10 c.f.m. air requirement per ton; 3. washed air versus dry air; 4. a five months' storage versus 3 months' storage; 5. 18-foot pile height versus 14-foot pile height and 20-foot pile height; 6. a 90-foot width pile versus 75-foot width versus 60-foot width, in the closed storage set-up. In other words, what we are attempting to study is the design of a permanent installation for sugar beet storage taking into consideration technical background which we have learned about to the present date on a cost basis. Fundamental costs are shown in table 1.

[1]Staff Engineer, Beet Sugar Development Foundation.

**Table 1.—Basis of cost estimates.**

| Description | Unit | Material | Labor | Total |
|---|---|---|---|---|
| Concrete and forms, reinforced | Cubic yard | $ 17.10 | $ 13.40 | $ 30.50 |
| Concrete and forms, plain | Cubic yard | 10.90 | 11.60 | 22.50 |
| Excavation | Cubic yard | ---- | .70 | .70 |
| Gates and grates for air control | Pound | .30 | Estimation | ---- |
| Hangers for conveyors | Ton | 100.00 | 35.00 | 135.00 |
| Insulation | Square feet | .06 | .04 | .10 |
| Lumber | M.F.B.M. | 70.00 | 90.00 | 160.00 |
| Pipe, reinforced concrete (Varies according to diameter) | L.F. | 1.00 to 6.50 | .30 to .80 | 1.30 to 7.30 |
| Pulleys, idler | Each | 8.00 | 2.00 | 10.00 |
| Pulleys, conveyor | Each | 40.00 | 2.00 | 42.00 |
| Purlins | Ton | 100.00 | 35.00 | 135.00 |
| Rails | Ton | 70.00 | 35.00 | 105.00 |
| Roofing | Square | 10.00 | 3.00 | 13.00 |
| Rubber belting | L.F. | 2.25 | ---- | 2.25 |
| Trusses | Ton | 100.00 | 35.00 | 135.00 |

Assuming that beets lost 1 pound of sugar per ton per day of storage, and supposing that permanent beet storage installations which would save half of that amount could be designed, an expenditure of $1.00 per ton for storage equipment and its operation on a storage period of 25 days would not be out of line with sugar valued at $ .08 per pound. Considering a storage period of 50 days it would seem that something less than $2.00 per ton could be spent on controlled storage.

### Two Different Plans Are Considered in This Cost Study

Plan A considers a pile of the open variety with all of the control operations carried on from the bottom of the pile. It consists of a system of underground tunnels at designated places throughout the piling area. Provision is made for varying the amounts of air to be introduced at various localities in the pile. Air washing possibilities are studied. The underground tunnel will be used for a drain as well as for a main conduit for the air. This plan is less complicated and less expensive from an installation viewpoint than is plan B.

Plan B.—This plan is the other extreme which goes all of the way towards complete control of the storage conditions. The pile is completely covered and a cross section of the building approximates a square set on a corner. Floors are of concrete. The roof is well insulated and covering is as air-tight as practically possible. Top vents may be used. Beets both enter and are discharged from the storage building by means of rubber belt conveyors. The loading and unloading station is at one point and the upper pile loading belts are just under the roof of the building. The lower belt for the pile discharge is underneath the building and just over the main air duct which will not be unlike the main duct for plan A. The blower house and air washer arrangement will also be somewhat similar to that of plan A. The Athey loader will not be required as the beets can be removed from the pile building by something similar to a fluming process, using the removal of grating at time intervals to affect the correct amount of discharge to the lower rubber belt conveyor. Regular tripping equipment may be used to discharge the upper pile loading conveyor.

### Summary

If permanent storage is to be further considered, the following basic information should be obtained.

1. Definite information should be secured on how high beets can be piled without damage.

2. Definite information on how long beets can be kept under various heights determined in the previous experiment.

Table 2.

| Open Pile 18 Feet High Closed Pile 90 Feet Wide | Material costs | Labor costs | Installation costs | Interest and maintenance | Operational costs | Cost per ton year 10-year basis | Cost per ton year 20-year basis | | |
|---|---|---|---|---|---|---|---|---|---|
| Open pile air at 20 CFM/T | $25,654.00 | $ 9,373.00 | $ 35,027.00 | $ 2,102.00 | $ 1,472.00 | $ .71 | $ .53 | Air alone | 5 months storage |
| Closed pile air at 20 CFM/T | 55,501.00 | 22,432.00 | 77,933.00 | 4,676.00 | 1,472.00 | 1.05 | .73 | | |
| Open pile air at 15 CFM/T | 16,974.00 | 7,357.00 | 24,331.00 | 1,460.00 | 1,069.00 | .50 | .37 | | |
| Closed pile air at 15 CFM/T | 52,276.00 | 21,896.00 | 74,172.00 | 4,450.00 | 1,069.00 | .95 | .65 | | |
| Open pile air at 10 CFM/T | 13,347.00 | 6,857.00 | 20,204.00 | 1,212.00 | 780.00 | .40 | .30 | | |
| Closed pile air at 10 CFM/T | 50,059.00 | 21,550.00 | 71,609.00 | 4,297.00 | 780.00 | .88 | .60 | | |
| Open pile air at 20 CFM/T | 35,733.00 | 12,008.00 | 47,741.00 | 2,864.00 | 2,278.00 | .99 | .75 | Washed air | |
| Closed pile air at 20 CFM/T | 66,652.00 | 24,239.00 | 90,891.00 | 5,453.00 | 2,278.00 | 1.34 | .96 | | |
| Open pile air at 15 CFM/T | 26,788.00 | 10,028.00 | 36,816.00 | 2,209.00 | 1,496.00 | .74 | .55 | | |
| Closed pile air at 15 CFM/T | 63,597.00 | 24,665.00 | 88,262.00 | 5,296.00 | 1,496.00 | 1.22 | .85 | | |
| Open pile air at 10 CFM/T | 19,628.00 | 8,489.00 | 28,117.00 | 1,687.00 | 1,050.00 | .56 | .41 | | |
| Closed pile air at 10 CFM/T | 56,515.00 | 2 ,107.00 | 79,622.00 | 4,777.00 | 1,050.00 | 1.04 | .71 | | |
| Open pile air at 20 CFM/T | 25,654.00 | 9,373.00 | 35,027.00 | 2,102.00 | 2,454.00 | .81 | .63 | Air alone | 3 months storage |
| Closed pile air at 20 CFM/T | 55,501.00 | 22,432.00 | 77,933.00 | 4,676.00 | 2,454.00 | 1.15 | .83 | | |
| Open pile air at 15 CFM/T | 16,974.00 | 7,357.00 | 24,331.00 | 1,460.00 | 1,781.00 | .57 | .45 | | |
| Closed pile air at 15 CFM/T | 52,276.00 | 21,896.00 | 74,172.00 | 4,450.00 | 1,781.00 | 1.02 | .72 | | |
| Open pile air at 10 CFM/T | 13,347.00 | 6,857.00 | 20,204.00 | 1,212.00 | 1,300.00 | .45 | .35 | | |
| Closed pile air at 10 CFM/T | 50,059.00 | 21,550.00 | 71,609.00 | 4,297.00 | 1,300.00 | .94 | .65 | | |
| Open pile air at 20 CFM/T | 35,733.00 | 12,008.00 | 47,741.00 | 2,864.00 | 3,796.00 | 1.14 | .90 | Washed air | |
| Closed pile air at 20 CFM/T | 66,652.00 | 24,239.00 | 90,891.00 | 5,453.00 | 3,796.00 | 1.49 | 1.11 | | |
| Open pile air at 15 CFM/T | 26,788.00 | 10,028.00 | 36,816.00 | 2,209.00 | 2,493.00 | .84 | .65 | | |
| Closed pile air at 15 CFM/T | 63,597.00 | 24,665.00 | 88,262.00 | 5,296.00 | 2,493.00 | 1.32 | .95 | | |
| Open pile air at 10 CFM/T | 19,628.00 | 8,489.00 | 28,117.00 | 1,687.00 | 1,750.00 | .62 | .48 | | |
| Closed pile air at 10 CFM/T | 56,515.00 | 23,107.00 | 79,622.00 | 4,777.00 | 1,750.00 | 1.11 | .78 | | |
| Separate comparison—3 months air supply 20/CFM/T | | | | | | | | | |
| Open pile height 14 feet | 27,535.00 | 11,392.00 | 38,929.00 | 2,336.00 | 1,472.00 | .77 | .58 | Air alone | |
| Open pile height 20 feet | 23,082.00 | 8,705.00 | 31,787.00 | 1,907.00 | 1,472.00 | .66 | .50 | | |
| Closed pile 60 feet wide | 71,632.00 | 24,330.00 | 95,962.00 | 5,758.00 | 1,472.00 | 1.34 | .93 | | |
| Closed pile 90 feet wide 20,000 tons of beets (3 months 20 CFM/T) | 89,736.00 | 35,833.00 | 125,569.00 | 7,534.00 | 2,994.00 | .94 | .65 | | |
| Open pile height 18 feet Air velocity main duct 5,000 FPM (3 months 20 CFM/T) | 23,277.00 | 7,771.00 | 31,048.00 | 1,863.00 | 1,755.00 | .67 | .52 | | |

Building fan shed above ground lowers cost per ton per year $.0103 on 10 year basis and $.0071 on 20 year basis.

Allowing for .3-inch increase in friction loss through washers the cost of washing air is $.02 higher on 10-year basis and $.01 higher on 20-year basis than shown.

Cost per ton per year of operating Athey loader and Silver piler on a 10,000 pile is $.34 for 10-year life and $.27 for 20-year life.

Costs per ton per year on closed pile figures are above the cost of operating Athey loader and Silver piler.

*Arguments for Plan A:*

1. Less costly installation.
2. Less maintenance.
3. Air washing possibilities available.

*Arguments for Plan B:*

1. Better control of temperatures.
2. Better control of humidity.
3. Should keep beets longer due to less freezing and heat damage.
4. Adapts itself to areas distant from factory location.
5. Can be designed to do work of piler and Athey loader.
6. Air washing possibilities available.

# 1947 Results of Beet Storage Pile Ventilation

L. J. HOLMES[1]

FORCED VENTILATION of a 2,500-ton pile of sugar beets with cool night air made it possible to store beets for a period of 35 days at Clarksburg, California, in 1946. During the 35-day storage period there was a loss of 0.94 pound of sugar per day per ton of beets stored, while a loss of 1.55 pounds of sugar per day per ton stored was incurred on a non-ventilated beet pile, in spite of the fact the beets were stored for only a 15-day period.

To further determine the possibility of moderately long periods of beet storage in the Clarksburg area, an experiment similar to the one run in 1946 was made in 1947. As in 1946, the regular non-vented factory pile was used as a check for the 1947 experiment.

## Experimental Procedure

Ventilator ducts were constructed using 2 by 12's for the sides, and with pieces of 2- by 12- by 18 inches spaced 1 inch apart on top. Several 2- by 6- by 18-inch pieces were nailed on the bottom to prevent collapsing. The 2- by 12- by 16-inch pieces on the first 10 feet of each 60-foot duct were placed tightly together to prevent the escape of air before it had reached some distance into the pile. Each 60-foot duct was placed 12 feet apart and they were arranged so that alternate vents would be exposed on each side of the pile for a distance of about 5 feet. The opposite ends of the vents (in the pile) were blanked off. Since the pile was 60 feet wide, these dead ends were approximately 8 to 10 feet of the opposite side of the pile. A total of fifteen 60-foot ducts were placed crosswise under a beet pile of 2,675.59 tons. This experimental pile was approximately 190 feet long, 67 feet wide at the bottom, 23 feet wide on top and 16 feet high.

Three fans were used for blowing air. Two of the fans were of the low-velocity type, each with a capacity of 2,000 cubic feet per minute, while the third was a high-velocity fan with a 1,500 cubic feet per minute capacity. The fans were coupled to the ducts with a heavy canvas tube making it fairly simple to move each fan from one duct to another.

To obtain the temperatures in the pile, a total of 23 thermocouples were installed under the direction of Coby Lorenzen of the University of California at Davis. The thermocouples were placed at levels 4 feet above the ground (12 thermocouples), at eight feet above the ground (8 thermocouples), and at 12 feet above the ground (3 thermocouples). Since the number of thermocouples was limited, all 23 of them were located in only about one-half the length of the ventilated pile.

[1]Manager, American Crystal Sugar Company, Clarksburg, California.

Temperature readings were obtained on the average of six times per day, or approximately every 4 hours for the period of the experiment.

## Experimental Results

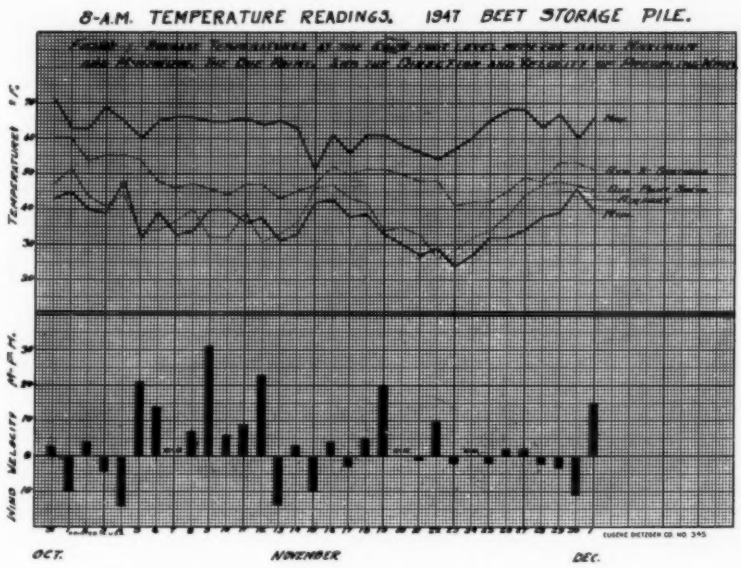
Piling was started October 20 and completed October 25. Only machine-topped beets went into the experimental pile. After the experimental pile was completed, piling of beets in the non-vented regular pile was begun, and continued until November 20. The weather during the storage period of 1947 was, in general, more favorable for beet storage than conditions experienced during the 1946 season. There were a preponderance of days with cool north winds, and this made it possible to open up the vents on the north side and allow for natural wind ventilation. It also made it possible to use the fans on the south side of the pile during the periods when north winds were blowing. As a result the fans could be used over the entire area of the pile in only half the time required if north winds had not been blowing. The three fans were run from approximately 7:30 p.m. to 7:00 a.m. every night, depending on outside temperature on three of the fifteen ducts during the storage period.

To be sure that adequate ventilation was taking place in the pile, smoke was blown through the vents three times during the latter part of the storage period. Since smoke was observed on the opposite side of the pile in about 15 seconds, and through the top of the pile to a width of 40 feet in 2 minutes, it was obvious that good air circulation was being obtained from the fans.

As may be noted from figure 1, the average temperature of the pile was 60 degrees Fahrenheit for the first 2 days of the storage period. The lowest average temperature of the pile was 41 degrees Fahrenheit, and was obtained November 23. From this date on, there was a gradual rise in average temperature until December 1 when the average temperature was 51 degrees Fahrenheit, at which time the experiment was concluded.

Figure 2 gives the average temperatures for the 4-, 8-, and 12-foot levels. Until November 17 the temperatures at the various levels were as normally expected, with the 4-foot level being the lowest, and the temperatures of the 8-foot level falling between the 4- and 12-foot levels.

On November 17 there was a slight drop in temperatures at the 4- and 8-foot levels, and a very marked drop in temperature at the 12-foot level, with the result that the 12-foot level was several degrees cooler than the lower two levels of the pile. Exactly what factors were responsible for this phenomenon are not known except that there was a total of 0.65 inch of precipitation November 15 to 16 with fairly low temperatures during the day November 17. Since the drop in temperature was much more pronounced at the 12-foot level there is the strong likelihood that the temperature of the pile at this level was affected by the cooling effect of the rain and also from the evaporation that took place.




Processing of the beets in the experimental pile was started November 29. For the most part, the beets were in a fairly crisp condition. There was only one spot where any amount of decay was found. This was due to a pile of trash which had completely decayed, destroying a small area of beets in the immediate vicinity. Undoubtedly this would have been a very large hot spot, except for the fact that the trash was located directly over a vent.

Of a total of 2,675.59 tons of beets which went into the experimental pile, 2,470.18 tons were recovered. This represents a shrinkage in weight of 7.67 percent. The average sugar of the beets into, and out of storage, was 15.80 percent. Calculated on a tonnage basis this shrink represents a loss of 0.59 pound of sugar per ton per day for the 41-day storage period.

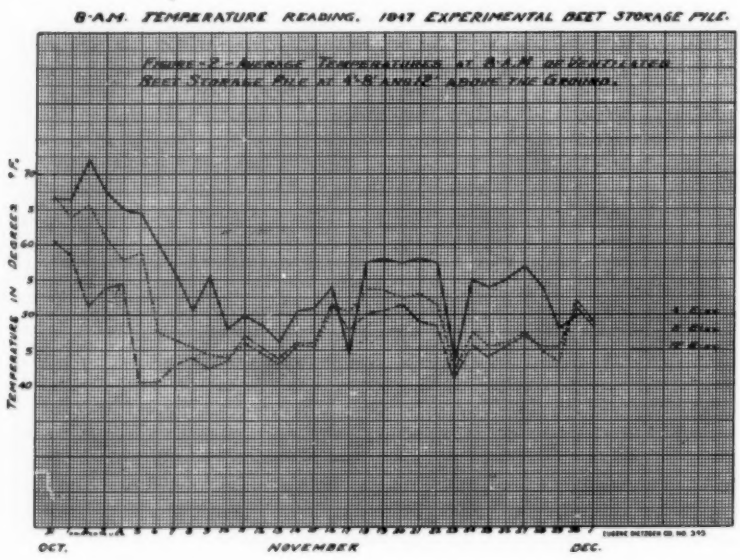
In the non-vented factory pile, beets were stored for an average of 17 days, and in this pile there was a loss of 0.73 pound of sugar per ton per day of storage.

## Conclusions

The results obtained from the experiments in 1946 and 1947 at Clarksburg, California, indicate that ventilated piles may be stored from late October to early December, for a period of 40 to 45 days, without too great a risk. Where piles are non-vented, severe loss may occur if the storage period is over 15 days, during the same season. With larger capacity fans it may be possible to still further cut sugar losses and probably lengthen the storage period in vented piles.

The main external factors which appear to affect the temperature of the beet pile are the cool north winds and the mean daily temperatures.

Experience in the piling of beets strongly favor piling only freshly topped beets. Under California conditions this requires the piling of only machine-topped beets which are only a couple of hours out of the field.


8 A.M. TEMPERATURE READING. 1947 EXPERIMENTAL BEET STORAGE PILE.
FIGURE 2 - AVERAGE TEMPERATURES AT 8 A.M. OF DIFFERENT AGED BEET STORAGE PILE AT 4', 8' AND 12' ABOVE THE GROUND.
TEMPERATURE IN DEGREES F.
OCT.
NOVEMBER
DEC.

# Ion Exchange

# Observations on Ion-Exchange Purification of Low-Grade Syrups in Conventional Beet Sugar Refining Methods

E. F. Berry and Robert S. Gaddie[1]

In 1947 an ion exchange pilot plant was installed at the West Jordan, Utah, factory to determine the feasibility of increasing the sugar-end capacity by decreasing the load on the low raw side of the house—this being the holding point at this particular factory. To do this, the new installation was applied to process intermediate green syrup (syrup from high raw centrifugals). It was anticipated that the plant would handle approximately one-fourth of the intermediate green syrup produced. After processing, the effluent syrup from the exchanger was to be returned to the factory thin juice for evaporation to thick liquor.

## Equipment

The installation includes a syrup dilution tank at the remelt station, a juice cooler or heat exchanger, a raw syrup storage tank, a sweet water storage tank, a battery of six exchanger tanks arranged to operate in the series, cation-anion, and three tanks for mixing regenerating agents. The pipe and valve sizes are all 2 inches. All tanks and pipe lines on the exchanger, and all acid mixing tanks and pipe lines are rubber lined. Valves are the Hills-McCanna rubber-lined diaphragm type.

One resin recovery trough is installed on the backwash header line leading from the cation tanks to the sewer, and another is on the backwash header from the anion tanks. These are nothing more than riffle boxes where the rate of flow of the backwash water coming from the tanks is decreased, thus enabling the riffles to retain any resins in suspension. Resins are taken from the anion backwash recovery trough periodically and returned to the various anion tanks. There is but little tendency for the cation resins to come over with the backwashing, and as a result it has not been necessary to return any cation resins to the exchanger battery.

The exchanger tanks are each 4 feet in diameter by 12 feet high. The design of the cation and anion tank is identical. The resin beds are 6 feet in depth with a volume of 75 cubic feet each. Resins used are cation C3 and anion A2 produced by Chemical Process Company. Each tank has three small glass-covered rectangular ports to enable the operator to view the inside of the tank to keep the liquid levels adjusted, and to insure that proper juice or regenerant flow is being maintained.

[1]Chemist, West Jordan, Utah, factory and General Chemist, Utah-Idaho Sugar Company, respectively.

## Operation

Syrup from the high raw centrifugal machines is diluted to 30 brix at the remelt dilution tank using either sweet water from the exchanger or factory thin juice when there is no exchanger sweet water. The exchanger sweet water furnishes but a small portion of the dilution agent necessary, and the thin juice is used the greater part of the time. The temperature of this diluted juice is then lowered from 60 degrees to 20 degrees Centigrade by pumping through the juice cooler at the head end of the exchanger supply tank.

The juice is then pumped into the exchanger battery where it makes a double pass through two pairs of exchangers operating in series alternating cation, anion before entering the factory thin juice. Thus, four of the tanks in the battery are in use in the juice cycle at one time while the other two are in the regeneration cycle. The juice enters the top of the first cation tank, runs through the bed into the first anion tank and into the sewer until the effluent syrup from the anion tank reaches one brix. This syrup is then turned into the factory thin juice. The finished juice runs until the limiting pH, purity, and color control point is reached. This control point will be discussed later. The only time that the juice makes this single pass is when the exchangers are first started up with all of the tanks completely regenerated and clean. The first pass juice is then turned into the second pair of exchangers and run to the sewer until the effluent from the anion tank reaches one brix. This effluent is then run as finished syrup directly into the factory thin juice. The exchanger syrup increases in brix gradually until it reaches 26 brix while maintaining the requisite purity. The brix of the hourly composite, however, will average 20. When the juice purity lowers until the control point is reached, the juice from the second exchanger pair is turned into the third exchanger pair which is then "sweetened on" in the regular manner and the effluent run into the finished juice line. At this point the resins in the first pair are completely exhausted and the intermediate green syrup is turned off from this pair which is then cut out of the cycle. Water is turned into this pair and the syrup washed from the cation through the anion and into the sweet water tank until the effluent reaches two brix. The beds are individually washed to the sewer, backwashed, drained to bed level, regenerated, washed, and are then ready for the next cycle. At the same time that the incoming syrup is shut off on the number one set, it is turned into the number two cation tank which then becomes the number one in the cycle. This makes the flow of incoming raw syrup continuous and of the finished syrup practically continuous except for the short sweetening-on period.

Differential air pressures are used to force the juice from one tank to another in the operating cycle. The air pressure is carried at 17 pounds per square inch on the first tank, at 15 pounds per square inch on the second, at 10 pounds per square inch on the third tank, and at not more than 5 pounds per square inch on the last tank from which the finished juice is taken.

## Control

The installation requires one operator per shift and one helper to make up the regenerating sulfuric acid and sodium hydroxide solutions on two shifts only. The regeneration tanks are of sufficient capacity to enable one shift to operate without refilling the tanks. Larger tanks, of course, would eliminate another of these helpers.

Control of the exchanger battery is maintained by keeping the apparent purity of the hourly composite of finished syrup above 90 percent based on the hourly laboratory analysis. Ninety percent was established as the lower control point on purity as this will give a juice of the same average purity as the white pan at the West Jordan factory. Another control used is that of color comparison. Samples of effluent syrup from the exchanger are diluted to the same brix as the regular factory thin juice and a color comparison is made. When the color of this diluted syrup becomes as dark as the color of the factory thin juice at the same brix, a new set of exchangers is cut into the cycle, and the first pair cut out, washed and regenerated. In addition, it has been found that by regulating the flow of the effluent at 15 gallons per minute and using the differential air pressures previously mentioned, one pair of exchangers will last 2 hours and 45 minutes as the number two pair in the cycle delivering finished syrup and another 2 hours and 45 minutes as the number one pair delivering the lower purity single pass syrup.

Thus a pair of exchangers will last 5½ hours before becoming completely exhausted. When spoiled beets are being cut and dark colored syrups result in all the factory juices and syrups, the life of an exchanger pair drops to 2 hours operating as the number two set or for a total time of only 4 hours. Thus, an excellent measure of control has been obtained by keeping the color of the effluent syrup lighter than the color of the thin juice and by taking one pair of exchangers out of the cycle and regenerating every 2 hours and 45 minutes.

Prior to the beginning of the operation a continuous recording conductivity meter was ordered, but up to the time of the writing of this report it had not been received. Information concerning the use of the recording conductivity meter as a control measure in regulating the length of the cycle is not presently available.

## Regeneration

The time required for "sweetening off," backwashing, draining to bed level, regenerating, and washing is approximately 2 hours. This allows sufficient time to keep one pair of clean exchangers on hand well in advance of the time needed for continuous operation. Sulfuric acid is used in regenerating the cation beds and sodium hydroxide in regenerating the anion resins. Approximately 315 pounds of sulfuric acid (specific gravity 1,835) made up to an 8-percent solution are used per regeneration. The last half of the sulfuric acid after passing through the cation bed is returned to the

acid mixing tank where the concentration is increased to 8 percent with the addition of new acid. This is then used for regenerating the next cation bed. Two hundred twenty-five pounds of sodium hydroxide are used for each anion regeneration. This is also made up to an 8-percent solution. None of the caustic solution is recovered. These amounts of regenerants were varied until a point was reached which gave maximum capacity for a minimum regenerant.

In addition to the acid regeneration the cation beds are regenerated once each week with 8-percent sodium hydroxide solution to displace the calcium sulfate in the beds and also to remove the proteins and other organic substances introduced into the beds from the juice. Large amounts of calcium sulfate are also precipitated out of the acid solution in the acid tank where the dilute acid returned from the exchanger is increased to 8-percent concentration. It is necessary to flush out this acid make-up tank once weekly to remove the deposits of insoluble calcium sulfate.

Wash water used in washing out syrup, backwashing, and washing out excess regenerants was taken from the condenser leg line of the low raw pan. The average temperature of this condenser water was about 50 degrees centigrade. As the operation got under way, the supply of wash water from this source was found to be insufficient, and it was necessary to supplement this water with water from the well supply. This reduced the average tem perature of the wash water to 30 degrees. The only advantage of the warmer water which we could detect was a slight decrease in the time required to wash out the syrup and caustic solutions.

After regeneration both cation and anion beds are individually washed to the sewer until the pH of the cation reaches 2.0. At this point the water from the cation is used in washing the anion. The small amount of acid introduced into the anion bed by this 2.0 pH water apparently has no effect on the capacity of the anion resin. However, we believe it serves to neutralize some of the small amount of residual sodium hydroxide retained by this bed.

## Discussion of Results

At the time this paper was written, the ion exchange plant had been in operation continuously for a period of 75 days, and after the first week there has been no measurable decrease in the capacity of the exchanger battery. Some invert sugar is made by the passage of the syrup through the exchanger. The average increase in invert sugar based on dry substance was 1.12 percent and the average temperature of the incoming raw syrup was 23 degrees. The increase in the amount of invert sugar has presented no difficulty in the regular factory control. As a result of the addition of the exchanger effluent to the evaporator supply syrup there has been no increase in the color of the factory thick juice, and no difficulties have been experienced in filtering or working sugar-end products. Determinations on final molasses have averaged about .5 percent of invert on dry substance. No problems have been experienced in Steffenizing this molasses.

Since the exchanger effluent has been added directly to the regular factory thin juice during the entire campaign, the only method of obtaining performance figures is to make comparisons with previous years. Such comparisons are shown in table 1 where the weighted averages for the previous 5- and 10-year periods are compared with results obtained this year.

Table 1.

| | % Sugar in beets | Purity beets | Tons sliced | Low raw mass. % in beets | Increase net extraction | Decrease molasses % beets |
|---|---|---|---|---|---|---|
| 10-year average | 15.814 | 84.52 | 74,474 | 9.7 | 4.04 | 1.10 |
| 5-year average | 15.742 | 84.36 | 90,303 | 9.9 | 4.70 | 1.22 |
| 1947 | 15.050 | 84.84 | 91.550 | 7.7 | | |

From this table it may be noted that while the average purities were approximately the same for the three periods, the net extraction was 4.04 percent greater this year than the 10-year previous period and 4.70 percent better than the previous 5-year period. Similarly, there was a decrease in molasses production of 1.10 percent on beets on the 10-year period and 1.22 percent on beets for the 5-year period. Also, it is interesting to observe the decrease on low raw massecuite percentage on beets from 9.7 and 9.9 to 7.7. This constitutes a decrease of approximately 25 percent in the amount of low raw massecuite to be processed.

To better illustrate the increase in net extraction resulting from the ion exchangers, a comparison between the relative purity of beets sliced and the net extraction for the past 15 years is shown graphically in figure 1.

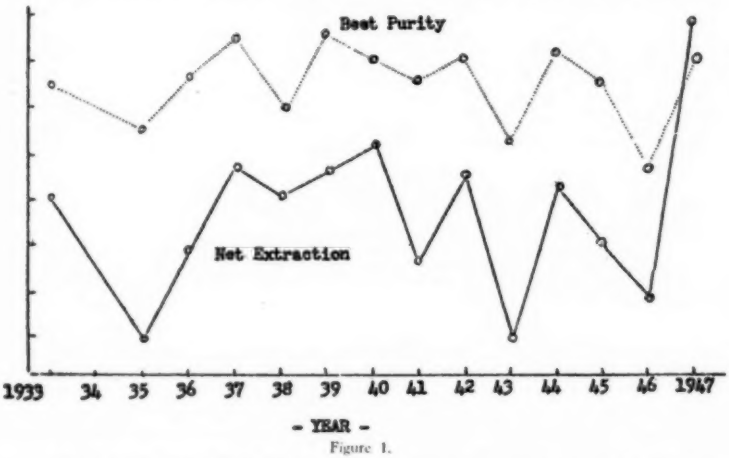



Figure 1.

It may be noted here that the net extraction practically parallels the beet purity curve and that it is approximately the same distance below it until 1947 where the two curves cross and the extraction becomes greater than the average beet purity.

The estimated costs and net returns resulting from the operation of the exchanger pilot plant are presented in table 2. The operating data in table 1 are used in these computations.

The net profit shown in table 2 does not include amortization of the initial cost of the exchangers, maintenance, resin losses, power, or fuel costs. The exchangers require very little maintenance and consequently these costs will be low. A total of only five pumps are required to pump all of the acid, caustic, and juice solutions, and of these only two are continuously in operation. Thus the power costs will be small. Inasmuch as the intermediate syrup is diluted mostly with thin juice, little additional fuel above that regularly required to evaporate the thin juice is needed to raise the exchanger syrup to the seventy brix thick juice level. A small amount of exchanger sweet water is used in diluting the raw syrup to thirty brix and also some dilution occurs in passage of the syrup through the beds. This will introduce a slight error when fuel costs are eliminated from the cost statement.

**Table 2.**

| | |
|---|---|
| **Operating costs per 100 tons of beets** | |
| Three exchanger operators and two helpers | $ 3.90 |
| Regenerants ($H_2SO_4$ and NaOH) | 9.90 |
| Total operating costs | $13.80 |
| **Net costs and returns per 100 tons beets based on previous ten years** | |
| Operating costs | $13.80 |
| Molasses not recovered at $40.00 per ton | 44.00 |
| Total costs | $57.80 |
| Credit on increased extraction sugar at 6.5 cents per pound | 79.04 |
| Net profits per 100 tons beets | $21.24 |
| **Net costs and returns per 100 tons beets based on previous 5 years** | |
| Operating costs | $13.80 |
| Molasses not recovered at $40.00 per ton | 48.80 |
| Total costs | $62.60 |
| Credit on increased extraction sugar at 6.5 cents per pound | 91.96 |
| Net profit per 100 tons beets | $29.36 |

In addition to the advantages enumerated in the above discussion, it has been found that the processing of a portion of the syrup which would normally go to make up the low raw pan has resulted in a much better control of the purities on the sugar end, particularly on the raw side. At times it is inevitable that purities of intermediate syrup will be too high to obtain a minimum loss of sugar in molasses. At such times most of this high-purity syrup can be processed through the exchangers until the regular sugar-end control has brought the intermediate syrup again to the requisite purity, thus saving the extra sugar which would be lost through the processing of one or two high-purity crystallizers. Conversely, during certain periods in the latter part of campaign, it is not uncommon for the purity of the West Jordan beets to drop to less than 80 percent. When this occurs, it

is very difficult to maintain sugar-end purities, especially on the white side, at high enough levels. Under such conditions, the ion exchange plant, still processing intermediate green syrup, may be used to great advantage.

### Summary

The ion exchange pilot plant at the West Jordan factory processing intermediate green syrup has worked successfully in supplementing the regular refining methods, and the installation has been limited in its function only by the pilot-plant size. Inasmuch as the West Jordan factory is equipped with a pulp drier and supplies molasses for one of the Steffen's factories in addition, it is not desired to eliminate molasses production entirely. However, with a larger plant, molasses production could be controlled from the demand by varying the quantities of syrup processed through the ion exchange plant.

An increase in capacity of 25 percent on the low raw side of the factory was realized with the installation. A substantial increase in extraction with a subsequent decrease in the amount of molasses produced as compared with averages for the previous 10 and 5 years at this factory was obtained. No detrimental effects in the normal processing of the mixture of this ion exchange effluent and the regular factory juices were observed. Sugar-end control of crystallizer purities was simplified. Higher white pan purities on juices from deteriorated beets were obtained.

# High Pressure Evaporation

FRED F. COONS[1]

AT THE PRESENT time there are only a few long tube vertical evaporator installations in this country in the sugar industry, one of which is located at Woodland, California. It is hoped, because of their novelty, that there will be interest in this dissertation, which will attempt to describe the various phases of high pressure evaporation in a beet sugar factory.

### General Description

Figure 1 shows a general cross section of a long tube vertical evaporator. Steam is introduced at the top of the tube bundle through an annular baffle and flows down and parallel to the outside of the tubes. Condensate and non-condensable gases are removed from the bottom just above the tube sheet. Juice enters the evaporator at the bottom and boils as it flows upward through the tubes. As the liquor evaporates large volumes of vapor are formed which cause vapor and juice to issue from the tubes at high

[1]Research Chemical Engineer, Spreckels Sugar Company, Woodland, California.

velocities. One might say that the action in a long tube vertical evaporator closely resembles that in a common household coffee percolator. The mixture of vapor and juice impinges on an umbrella-shaped deflector plate as it leaves the tubes causing the liquor to become separated from the vapors. Vapors pass above the deflector plate through a vapor outlet to an external centrifugal entrainment separator where further juice and vapor separation takes place. Juice after hitting the deflector plate is forced downward to an annular space around the tube bundle to which a juice outlet line is connected. A vapor-liquor seal is maintained in this line by a ball-float device that maintains a level in a small chamber. The juice is then throttled to the next effect.

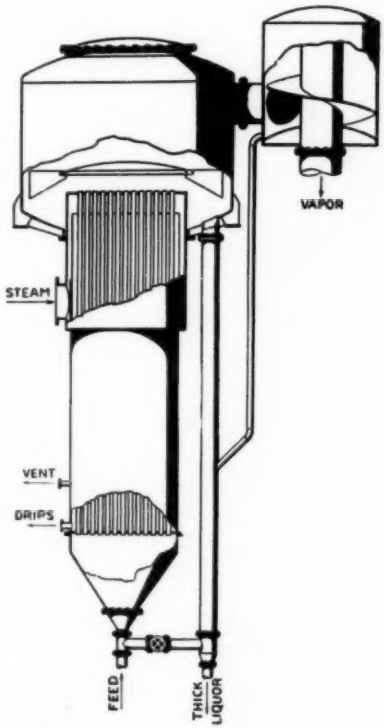



Figure 1.—Long tube vertical evaporator.

Tube sizes and composition are varied depending on the installation and the material to be evaporated. Tube sizes range from 1 to 2 inches in diameter and are from 16 to 24 feet long. Tubes are made from iron, copper, brass or any special alloy as the use demands, and are rolled into the tube sheets.

In the sugar industry steam and juice flow in parallel so that the more concentrated sugar juices are subjected to lower temperatures. First effect steam pressures are usually maintained between 25 and 50 pounds, and last effect vacuum is kept between 20 and 28 inches of Mercury.

## Sugar Destruction

When thin juice is exposed to high temperatures for prolonged periods of time it will invert, decompose and caramelize, forming dark-colored juices. However, in the long tube evaporator the retention time is so short that no serious degradation occurs.

Figure 2 shows a calculated time-temperature curve for thin juice as it passes through the thin juice heater and evaporator first effect in the Woodland installation. Many assumptions were made in this estimation; thus the results are only approximations. Experimental work has been conducted, subjecting thin juice to temperatures for the same times as those in the time-temperature curve and the results showed little or no degradation. Figure 3 shows a diagram of the apparatus used. Oil baths were used to simulate the temperatures of the juice for the given periods of time. The resulting time-temperature curve is seen in figure 2 showing the experimental approach to the calculated curve. The experimental data are tabulated in table 1. Slight increases in color of the thin juice were noticed which were due to caramelization, but again, were not significant.

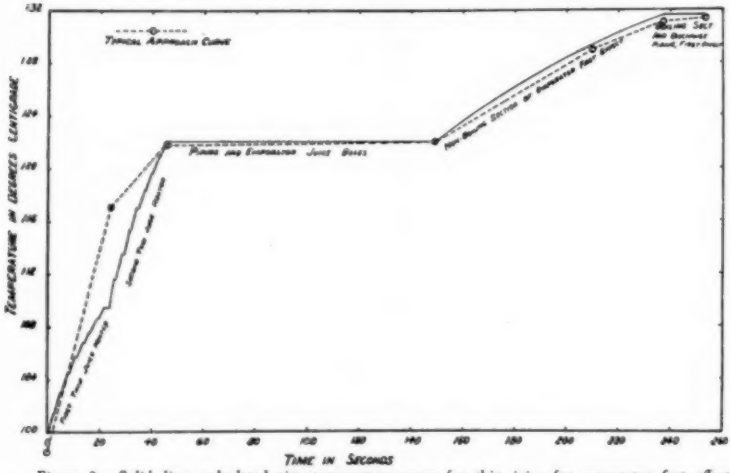



Figure 2.—Solid line, calculated time-temperature curve for thin juice for evaporator first effect and preheaters. Dotted line, experimental time temperature curve showing the approach to the calculated curve.

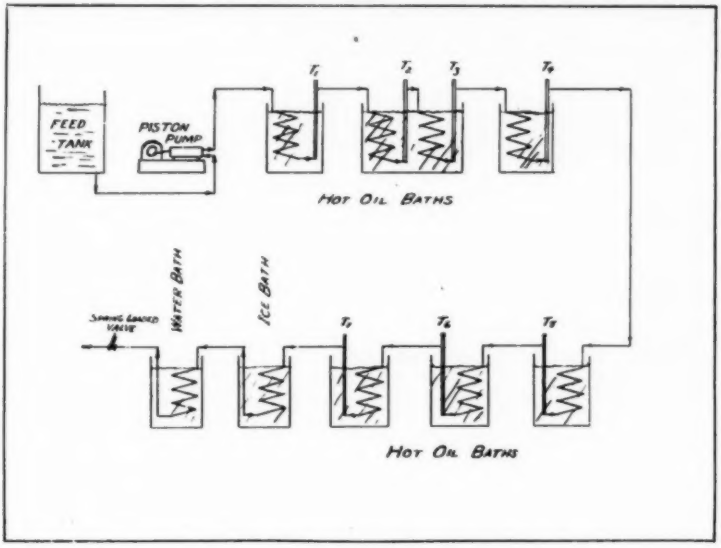



Figure 3.—Experimental apparatus for obtaining time-temperature curves.

## Description of the Woodland Installation

Previous statements in this paper have been concerned with long tube vertical evaporators in general, we will now confine ourselves to the installation in Woodland.

At Woodland we have a five effect evaporator manufactured by the Swenson Evaporator Company. Four of the effects are the long tube vertical type and the fifth is a calandria type. The first and second effects each consist of two identical bodies operated in parallel. The remaining effects are single bodies. Evaporator bodies used in the first, second and third effects are of the same size, each having 950-1½ inch O.D. 14 B.W.G. tubes 18 feet long. The fourth effect is somewhat smaller containing only 398 tubes. The calandria fifth effect has 1,120-2½ inch O.D. 12 B.W.G. tubes 4½ feet long. This gives the first effect 12,000 square feet; the second effect 12,000 square feet; the third effect 6,000 square feet; the fourth effect 2,500 square feet; and the fifth effect 3,200 square feet heating surface.

## Tube Corrosion

Originally the tubes were made from iron throughout the evaporator, but serious corrosion and pitting of the iron tubes were experienced. Iron tubes had an average life of about 3 years, with many failing much before this time, causing many expensive interruptions in service. After testing

various tubes, the first and second effects are now completely tubed with brass. Some of the brass tubes have been in operation 5 years with very little corrosion. Eventually the entire evaporator will be tubed with brass when our present stock of iron tubes is depleted. The first two effects were considered the most important as any interruption in their service would seriously reduce the capacity of the evaporators.

### Steam and Juice Flow System

During operation approximately half of the thin juice is fed to evaporator 1A and half to 1B. Product from 1A feeds 2A and 1B feeds 2B. Products from the second effects are combined to feed the remaining effects in series. See figure 4. Vapors from both first bodies are joined in a common entrainment separator and then are divided to each second body. The same system is used in the second effect.

When one body is out of operation for boil-out, vapors are withdrawn through a 6-inch header to a special boil-out condenser. When one of the first bodies is out of service, some exhaust steam is by-passed to first vapors to make up the deficiency. Similarly some of the feed is led directly to the second effect in order to maintain the capacity.

### Vapor Heating

One of the most important advantages of the long tube vertical evaporators is in the overall steam economy resulting from complete utilization of vapors for process heating and evaporation. Table 2 shows an outline of the vapor distribution as used in the Woodland factory. First vapors are used in:

White pans
Thin juice heaters

Second vapors are used in:

Intermediate pans
Second-carbonation heater
Thin juice boiler
Thin juice heater
High and low melters (open injection)
Cold waste heater (open injection)
Saccharate milk heater (open injection)

Third vapors are used in:

Battery
Raw juice heater
Second-carbonation filter heater
Standard liquor heater
Raw pans

Fourth vapors are used in the raw juice heater.

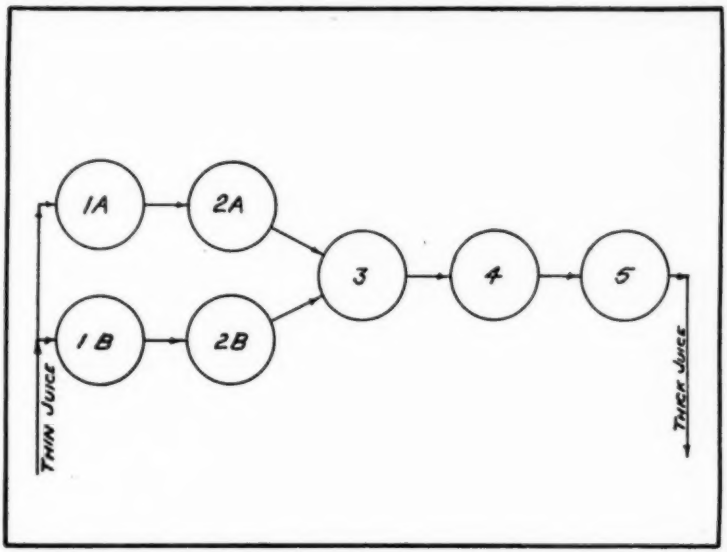



Figure 4.—Flow diagram for Woodland evaporators.

-3-

| | | | Orig | Test No. 1 | 2 | 3 | Change |
|---|---|---|---|---|---|---|---|
| June 11 | Sugar Solution unboiled water pH ca-4 | Polarization, A | 13.27 | 13.26 | 13.27 | 13.24 | Not |
| | | " C | 0.03 | 0.05 | 0.01 | 0.02 | sign. |
| | | % Invert on Poln | 0.02 | 0.08 | 0.08 | 0.08 | +0.06 |
| June 12 | Sugar Solution unboiled water pH ca-4 | Polarization A | 12.36 | 12.32 | 12.32 | 12.33 | Not |
| | | " C | 0.03 | 0.00 | 0.02 | 0.00 | sign. |
| | | % Invert on Poln | 0.02 | 0.12 | 0.13 | 0.13 | +0.11 |
| June 13 | Thin Juice | Polarization, A | 11.54 | 11.50 | 11.52 | 11.54 | Not |
| | | " C | 0.04 | 0.04 | 0.05 | 0.05 | sign. |
| | | % Invert on Poln | 0.23 | 0.24 | 0.25 | 0.25 | +0.02 |
| June 17 | Sugar Solution unboiled water pH ca.4 | Polarization, A | 12.44 | 12.39 | 12.38 | 12.41 | Not |
| | | " C | 0.05 | 0.05 | 0.02 | 0.04 | sign. |
| | | % Invert on Poln | 0.02 | 0.08 | 0.09 | 0.09 | +0.07 |
| June 18 | Thin Juice | Polarization, A | 10.14 | 10.10 | 10.11 | 10.12 | Not |
| | | " C | 0.05 | 0.07 | 0.04 | 0.06 | sign. |
| | | % Invert on Poln | 0.26 | 0.26 | 0.26 | 0.26 | 0.00 |
| June 20 | Thin Juice | Polarization, A | 10.12 | 10.09 | 10.06 | 10.06 | Not |
| | | " C | 0.03 | 0.04 | 0.02 | 0.02 | sign. |
| | | %Invert on Poln | 0.28 | 0.32 | 0.32 | 0.32 | +0.04 |
| June 21 | Sugar Solution boiled water pH about 7 | Polarization, A | 11.08 | 11.05 | 11.09 | 11.10 | Not |
| | | " C | 0.03 | 0.02 | 0.04 | 0.04 | sign. |
| | | % Invert on Poln | 0.02 | 0.04 | 0.05 | 0.05 | +0.03 |

| July 1 | Sugar Solution boiled water pH about 7 | Polarization,A | 12.26 | 12.26 | 12.27 | 12.28 | Not |
|---|---|---|---|---|---|---|---|
| | | " C | 0.02 | 0.03 | 0.04 | 0.03 | sign. |
| | | %Invert on Poln | 0.00 | 0.01 | 0.01 | 0.01 | /0.01 |

SUMMARY OF AVERAGE RESULTS

| | Sugar Sol'n pH. 4 | Sugar Sol'n pH.7 | Thin Juice |
|---|---|---|---|
| Polarization | No change | No change | No change |
| Increase in invert on pol'n | 0.08 | 0.02 | 0.02 |

Table 1.—Experimental results for sugar destruction by heat.

At times it has been necessary to by-pass second to third vapors in order to maintain circulation in the raw pans and maintain sufficient heat for proper battery operation. This procedure is not recommended unless it is absolutely necessary because it cuts down the overall steam economy of the factory.

## Normal Operating Procedure

The usual method of operation, assuming a constant rate of slice, is to keep the exhaust steam pressure at the maximum allowable figure considering the mechanical and the steam load. This runs between 40 and 45 pounds at Woodland. Live steam is exhausted from about 300 pounds to the exhaust steam pressure through the turbine and is kept at the desired figure by bleeding live steam through a pressure reducing valve to the exhaust steam line. This is possible because the steam load is greater than the mechanical load. When the evaporator becomes so dirty that the mechanical load exceeds the steam load, steam is blown to the roof by a pressure relief valve at 46 to 47 pounds. Generally this condition is not allowed to be reached.

If the evaporators are extremely clean and the operator wishes to reduce the capacity, he first closes down on the amount of water flowing to the jet condenser which reduces the vacuum causing a decrease in the overall temperature drop and thereby reducing the capacity. If further reduction is required, fourth vapors are backed up by throttling the valve to the fifth effect. This reduces the temperature drop across the first effects where most of the evaporation takes place. If still further reduction is necessary the exhaust steam pressure is then reduced.

THEORETICAL HEAT BALANCE
Steffen House - Kansas Molasses
(Saccharate Purity 90.3)

1000 Tons Beets &OT Excess Mol
16 Percent Sugar - Total Mol = 151.07

| Item | Station | Lbs Wt. | Temp Ent | Temp Leave | Temp Diff | °F | % On Beets | BTU per 100# Beets | Mbh Bl. | 1st Vap | 2nd Vap | 3rd Vap | 4th Vap |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Steam Pressure #/in² Ga | | | | | | | | 40 | 30 | 17 | 5 | 8"Hg. |
| | Steam Temp °F | | | | | | | | 287 | 274 | 254 | 227 | 197 |
| | Steam Temp °C | | | | | | | | 141.3 | 134.5 | 123.3 | 108.3 | 917 |
| | Latent Heat Vapor (Exhaust &0°Bé) | | | | | | | | 952 | 931 | 945 | 962 | 981 |
| 1 | Calorimeters-Cossettes Entering | 1.00 | 30 | | | 34 | 100.0 | 5400 | | | | | |
| | Water Entering | 1.00 | 50 | | | 90 | 243.0 | 21800 | | | | | |
| | Total Heat | | | | | | | 27200 | | | | | |
| | Diffusion Juice Leaving | .95 | | 60 | | 108 | 142.0 | 14400 | | | | | |
| | Wet Pulp and Water | 1.00 | | 60 | | 108 | 200.0 | 21600 | | | | | |
| | Total Heat | | | | | | | 36200 | | | | | |
| | Total Heat Input | | | | | | | 9000 | | | | 9.35 | |
| 2 | New Juice Heater | .95 | 60 | 72 | 12 | 21.6 | 142.0 | 2910 | | | | | 2.97 |
| | New Juice Heater | .95 | 72 | 85 | 13 | 23.4 | 142.0 | 3160 | | | | 3.28 | |
| 3 | Second Carbonation Heater | .95 | 80 | 92 | 12 | 21.6 | 174.55 | 3580 | | | 3.79 | | |
| 4 | Second Filter Heater | .95 | 89 | 92 | 3 | 5.4 | 174.55 | 890 | | | | .93 | |
| 5 | Thin Juice Boiler | .95 | 88 | 101 | 13 | 23.4 | 174.55 | 3880 | | | 4.11 | | |
| 6 | Thin Juice Heater | .95 | 96 | 111 | 15 | 27 | 174.55 | 4480 | | | 4.75 | | |
| | Thin Juice Heater | .95 | 111 | 126 | 15 | 27 | 174.55 | 4480 | | 4.82 | | | |
| 7 | High and Low Melter (Open Inj) | .60 | 75 | 85 | 50 | 90 | 51.49 | 2780 | | | 2.78 | | |
| 8 | Std. Liquor Heater | .60 | 85 | 95 | 10 | 18 | 51.49 | 560 | | | | .58 | |
| 9 | White Pan Evap'n | Latent Heat = | | | 992 | | 12.33 | 12230 | | 13.58 | | | |
| 10 | Inter Pan Evap'n | Latent Heat = | | | 992 | | 4.22 | 4190 | | | 4.64 | | |
| 11 | Raw Pan Evap'n | Latent Heat = | | | 1018 | | 2.58 | 2630 | | | | 2.41 | |
| 12 | Receiving Tanks | 100' 1 1/2"O.D.Cu. Tubing | | | | | | 460 | .85 | | | | |
| 13 | Cold Waste Heating (Open Inj) | 1.00 | 18 | 90 | 72 | 129.6 | 79.8 | 10346 | | | 10.36 | | |
| 14 | Saccharate Milk Ht (Open Inj) | 1.00 | 40 | 85 | 45 | 81 | 72.0 | 3290 | | | 3.29 | | |
| | Total Vapors % On Beets | | | | | | | | .85 | 18.20 | 37.62 | 16.33 | 2.97 |
| | Total BTU | | | | | | | | | 16910 | 32880 | 15930 | 2910 |
| | Water Evaporated In Evaporators | | | | | | 137.07 | | 68.30 | | | | |
| | Steam to Granulators | | | | | | | | .58 | | | | |
| | Steam To Beet Cutters | | | | | | | | 1.25 | | | | |
| | Steam To Turbines (Electrical and Mechanical Power) | | | | | | | | 6.60 | | | | |
| | Total Steam % On Beets = 25497 = 17# Ga, L = 945 | | | | | | | | 77.30 | | | | |
| | Total Steam % On Beets F A A 212 F, L = 970 | | | | | | | | 73.30 | | | | |
| | Lbs. of Steam per Ton of Beets F & A 212°F | | | | | | | | 1526 | | | | |
| | Lbs. of Steam per Bag of Sugar F & A 212°F | | | | | | | | 406 | | | | |
| | Gas = 1040 BTU - 82% Boiler Eff. (Cu.Ft. per Ton Beets) | | | | | | | | 1710 | | | | |
| | Tons per Bag of Sugar 96.8% Produced of Total Entered | | | | | | | | 441 | | | | |
| | BTU per Bag of Sugar | | | | | | | | 480,000 | | | | |
| | Oil Percent On Beets-(18,500 BTU Oil. 86% Boiler Eff.) | | | | | | | | 3.86 | | | | |

Table 2.—Theoretical heat balance, Steffen house, showing vapor utilization.

## Heat Balance

In normal operation according to the theoretical heat balance no steam reaches the last effect. Only when an evaporator body is out of service or the capacity of the vapor demand is reduced do we have any heat reaching the fifth effect. In table 3 we have a heat balance of our evaporators made from data taken from 120 days of the last campaign. Note that steam is reaching the last effect in a quantity greater than is available from the fourth effect. This indicates that there is considerable by-pass of vapors and probably errors in the data. This heat balance does not include the additional heat gained from condensate flash, but this is assumed to be approximately equal to the amount of heat lost due to radiation and conduction.

The actual heat transfer coefficients in the first two effects are considerably less than the design coefficients which fact further accounts for the vapor pressures being lower than anticipated.

**HEAT BALANCE, HOUSE EVAPORATORS**

120 DAYS 1947 CAMPAIGN, SPRECKELS SUGAR CO, WOODLAND
2100 T, 620 GPM AT 250°F, 13.0 RDS, 87 APC, VACUUM, 21.3", 155.5°T

ASSUME HEAT LOSS TO BE EQUAL TO HEAT GAINED BY CONDENSATE FLASH.

| EFFECT | I | II | III | IV | V |
|---|---|---|---|---|---|
| CHEST PRESSURE | 40.2# | 22.9# | 10.1# | 2.1# | 9.1" |
| TEMP. OF STEAM, °F. | 286.9 | 263.5 | 239.6 | 218.8 | 194.0 |
| HEAT TO CHEST BTU/HR x $10^{-3}$ | 121,954 | 72,560 | 19,905 | 6,520 | 9,653 |
| TEMP. OF LIQUOR OUT, °F. | 264.5 | 241.6 | 221.5 | 197.0 | 158.9 |
| AMOUNT OF FLASH, °F. | -14.5 | 22.9 | 20.1 | 24.5 | 38.1 |
| JUICE TO EVAP. #/HR x $10^{-3}$ | 325.8 | 200.3 | 119.6 | 96.78 | 88.20 |
| SPECIFIC HEAT | 0.95 | 0.93 | 0.85 | 0.80 | 0.77 |
| HEAT IN FLASH BTU/HR x $10^{-3}$ | -4,486 | 4,266 | 2,043 | 1,897 | 2,588 |
| HEAT AVAILABLE FOR EVAP. BTU/HR. x $10^{-3}$ | 117,468 | 76,826 | 21,948 | 8,417 | 12,241 |
| WATER EVAP. #/HR. x $10^{-3}$ | 125.5 | 80.7 | 22.72 | 8.58 | 12.18 |
| JUICE FROM EVAP #/HR x $10^{-3}$ | 200.3 | 119.6 | 96.78 | 88.20 | 76.02 |
| R.D.S. OUT | 21.2 | 35.4 | 43.7 | 48.0 | 55.7 |
| HEAT OFF TO PROCESS BY DIFF. BTU/HR x $10^{-3}$ | 44,908 | 56,921 | 15,421 | -1,236 | — |
| HEAT OFF TO PROCESS THEORETICAL, BTU/HR x $10^{-3}$ | 29,600 | 57,500 | 18,000 | 5,090 | — |
| $\Delta T$, TEMP. DIFF. °F. | 22.4 | 21.9 | 18.1 | 21.8 | 35.1 |
| HEATING AREA, SQ. FT. | 12,000 | 12,000 | 6,000 | 2,500 | 3,200 |
| $U\Delta T$, BTU/HR/SQ. FT. | 10,163 | 6,047 | 3,317 | 2,608 | 3,017 |
| U, HEAT TRANS. COEFF. BTU./HR/SQ. FT./°F | 454 | 276 | 183 | 120 | 86 |
| ASSUMED B.P.R. AND PRESSURE LOSS, °F. | 1.0 | 2.0 | 2.7 | 3.0 | 3.4 |
| G.P.M. PER TUBE | 0.336 | 0.194 | 0.207 | 0.407 | — |
| BOILOUTS | 7 | 8 | 6 | 4 | 4 |

Table 3.—Heat balance, Woodland evaporators for 1947 campaign.

## Factors Affecting Heat Transfer

Why the low heat transfer coefficients? This may be due to several different causes. One might be the failure to completely remove the non-condensable gases. The general agreement between evaporator experts is that non-condensable gases are swept along with the steam and can be most effectively removed at the end of their path. This is the point in the

long tube evaporator where all of the vapors have been condensed and is located at the bottom of the steam chest. Many operators feel that the non-condensables should be removed at the top of the steam chest.

The second reason, and the more likely, is the very rapid scaling rate which may be caused to a certain extent by improper design. Note that in table 3 the calculated flow rate in GPM per tube is approximately 1/3, 1/10, 1/10, 2/5 in the first four effects, respectively. In some recent pilot evaporator experiments, which are however not conclusive, it was shown that the evaporator tubes scale at an accelerated rate at the low flow rates, with 1/3 GPM per tube being about the lowest rate that can be handled with the normal scaling rate. To further aggravate the situation there is the possibility of the channeling of the flow to certain tubes leaving the others in comparative dryness. The main reason for increased scaling at these low flow rates is that the juice has an opportunity to "stew" and reach higher temperatures and higher local concentration which in turn causes scaling. In some pilot evaporator studies we have obtained as much as three times the heat transfer coefficients by operating at higher flow rates with very slight scaling. Values of 700, 800, 700, 450 were not uncommon in the first four effects, respectively, after many hours of operation. Note that the factory averaged only 500, 300, 200, and 100. However, channeling is no problem in our pilot evaporator because of its size. One way to increase the flow rate per tube and yet maintain the same overall heating area is to decrease the number of tubes and increase their length.

## Scale and Scale Removal

The scale found in our evaporator tubes is similar to that found in any beet sugar evaporator consisting mainly of calcium oxalate, carbonate and sulfate. The exact composition of course, is dependent on the nature of the beets being handled.

Scale in the long tube evaporator cannot be readily removed by mechanical methods and thus chemical procedures are used. Based on experience the following method has been found satisfactory in most instances: After removal from service the evaporator body is filled with a 4-percent caustic soda and soda-ash solution and is boiled for 3 or 4 hours allowing the solution to circulate up through the tubes and down the discharge line and so on. It is then followed by a water rinse to wash out the remaining traces of caustic. Now it is boiled an additional 3 hours on a 3-percent inhibited hydrochloric acid solution. After the final rinse the evaporator tubes are generally clean.

## Summary

Summarizing our experiences with the long tube vertical evaporator we have found them to be entirely satisfactory in spite of their lower than anticipated heat transfer coefficients because of their great overall saving in steam. No doubt with further experimental work the reasons and the remedies for these discrepancies can be found and a better design can be made.

# Full-Scale Ion Exchange Operations at the Hardin Plant of the Holly Sugar Corporation

E. A. Haagensen[1]

A FULL-SCALE ion exchange plant was installed at the Hardin, Montana, factory of the Holly Sugar Corporation in 1947. The plan was to have the unit ready for operation at the start of campaign. However, delays in construction occurred and the ion exchange did not go into operation until November 27 and, because of minor adjustments, the plant did not operate continuously until November 30. The campaign finished December 21. During this period, all the juice from 36,550 tons of beets was processed by ion exchange. The results have not been completely analyzed and evaluated at this time, but a preliminary report on this question is deemed worthwhile.

## Plant Description

The plant consists of four pairs of cells, each pair being one cation exchange cell and one anion exchange cell. All cells are identical in size and mechanical design. They are 10 feet in diameter by 10 feet straight side height with ASME spun heads, and are designed for 60 pounds per square inch working pressure. Rubber lining is used throughout and suitable underdrain, feed and overflow distributors of chemical resistant materials are installed in each. Each cell contains 410 cubic feet of the necessary resin (cation or anion), giving a bed depth of 5 feet, 3 inches.

All piping in contact with sugar juices or regenerant liquids is rubber lined. The valves used are Saunders type with a rubber diaphragm and are completely rubber lined when installed in rubber-lined piping. These valves are operated by air pistons controlled by solenoid pilot valves which are in turn controlled by switches and relays on the control panel.

The control panel which is 20 feet by 8 feet by 3 feet, 6 inches, is dust and moisture proof and contains the controlling relays and instruments. On the face of the panel are mounted the instrument dials and the numerous control switches. The switches for operating the valves are grouped in five sets. One set is for the valves common to all cells and each of the other sets applies to the valves for each pair of cells. These switches have three positions, viz:—off, manual and automatic. When in the automatic position, various steps in the process involving several valves and pumps are controlled by a series of push buttons, thus minimizing errors involved in the human element.

The instruments consist of flow indicators on acid, ammonia, sweet water, cation and anion backwash, rinse water and reclaimed water; flow

indicators and recorders in ingoing and outgoing juice; recording and indicating pH meters on cation and anion effluent; and conductivity indicators and recorders on untreated juice, cation and anion effluent, sweet water and rinse water.

The regeneration of the cation cell is three-stage, using 5 to 6 percent sulfuric acid. On the anion cells it is single stage, using 2 percent ammonia.

The juice to be treated is cooled by passage through spiral type heat exchangers on the other side of which is the outgoing treated juice from ion exchange, which is warmed up at the same time. Since this cooling is not enough, the incoming juice, after passage through the heat exchangers, is further cooled in a tubular cooler by means of factory supply water.

In addition, there are the necessary accessory equipment such as pumps, air compressors, tanks and storage facilities for the process.

The equipment is housed in an addition to the factory as a separate unit yet an integral part of the factory. It is so designed that normal operation of the factory may be resumed merely by opening and closing three valves.

## Process

The process used was that involving treatment of second-carbonation juice. Filtered second-carbonation juice was cooled to below 20 degrees Centigrade to minimize inversion in the subsequent passage through the acid conditions of ion exchange. After cooling, the juice was pumped through one pair of cells; it first passed through the cation cell and then through the anion cell. This flow was continued until one of the pH meters or conductivity meters indicated that break-through had been reached. This indication was a rise in pH of cation effluent or a fall in its conductivity, or a fall in pH of the anion effluent or a rise in its conductivity. Any one or more of these indications was used as a criterion for determination of the end of a treatment cycle.

A detailed explanation of the process is not presented here, since various phases of the actual steps taken are rather well known and have been in use some time in small-scale units. However, it will be well to explain the decision to operate the ion exchange on second-carbonation juice. The treatment of raw juice is desirable from the viewpoint of elimination of lime and the accompanying kiln, carbonation, thickeners and filters. However, the process of treating raw juice still presents problems that have not been economically solved. In addition, the exchangeable ion load per ton of beets is 25 to 35 percent higher for raw juice than for filtered second-carbonation juice. Second-carbonation juice was chosen instead of sulfured thin juice because of the possibility of eliminating the purchase of sulfur. The desirability of this is not definite. It is known that oxidizing agents or substances are harmful to the anion exchange resins. Such oxidizing agents might be reduced by the use of sulfur dioxide and rendered harmless to the anion resin. This is a question that will require further study.

## Results Obtained

The results during the brief operation at the end of campaign are probably not a true picture of ion exchange, since they were obtained when treating beets that had been in storage for some time. The beets were in relatively poor condition a good deal of the time. Soft and sour beets were common and many were black and dried out. Table 1 shows the average results for a day's operation.

Table 1.

| | Feed 2nd-carbonization juice | De-ionized juice |
|---|---|---|
| Brix | 12.5 | 9.6 |
| Purity | 89.6 | 97.6 |
| Percent sugar | 11.0 | 9.5 |
| Conductivity mmhos | 4325 | 245 |
| Nigrogen* | 126 | 55 |
| pH | 9.2 | 7.5 |
| Percent dilution | | 15.8 |

*An arbitrary nitrogen coefficient.

From table 1 it may be seen that, based upon purities, there is a non-sugar removal of 82.5 percent. The nitrogen removal is 56 percent. This is total nitrogen and is an indication of the organic removal. No determinations were made on ash removal, however, the conductivities may be taken as an approximation and indicate a 94 percent elimination. The percentage dilution is calculated on sugar content. The remaining loss in brix is due to removal of non-sugars. The dilution varied from 13 to 16 percent throughout the period.

Graph No. 2 shows the brix of the affluent of a pair of cells during sweetening-on plotted against effluent flow. The flow is expressed as percent of the total resin volume in both exchanger beds. The indication of brix in the effluent up to about 55 percent of the flow is not well accounted for. If it is presumed that there is some short circuiting of the incoming juice, it would be assumed that this brix should uniformly rise from zero. No tests were made on actual sugar present in this effluent by other means, but it is thought that this is not sugar but other substance. From the graph, it can then be seen that the brix is substantially zero up to 55 percent of bed volume, and then rises to full brix at 115 percent.

Graph No. 3 shows a similar plot of brix versus flow on the effluent during sweetening-off. Here again the effluent comes out at full brix of the solution in beds until about 55 percent flow and at 115 percent flow has about reached a minimum and is starting to level out. On sweetening-off, the purity of the effluent also drops. A good portion of the brix present in the effluent is due to non-sugars being displaced from the bed by the salts in the raw water used to sweeten off.

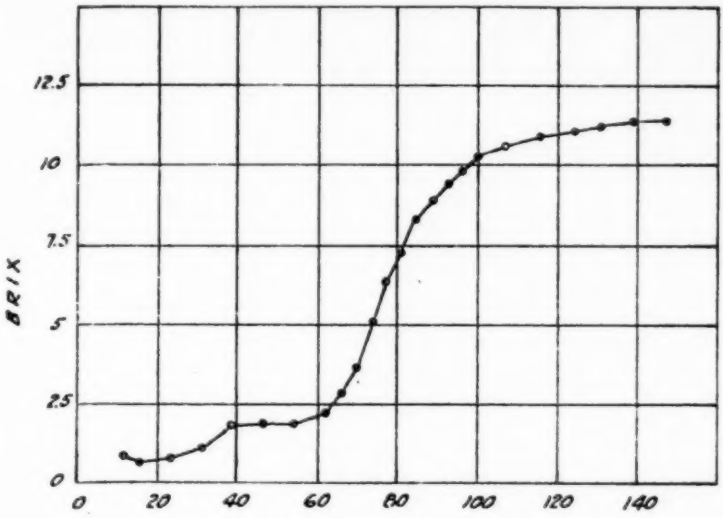



FIG. 1.—SWEETENING-ON

From a theoretical analysis of the resin beds, there is a total liquid content of a given volume resin of about 62 percent. The actual inter-granular voids are approximately 47 to 48 percent; the other 14 to 15 percent is the intra-granular voids or solution actually held in the gel structure of the resin. The inter-granular voids are displaced rather completely by incoming liquid, while the intra-granular voids are removed by a leaching action. The apparent discrepancy between 48 percent and the 55 percent on the graph is due to 1—the extra liquid in pipe lines and above the beds and 2—the fact that the displacement is not 100 percent efficient.

During the short period of operation, the quantity of chemicals used was varied quite widely. Good results were obtained with 25 pounds of 93-percent sulfuric acid and 6 pounds of anhydrous ammonia per ton of beets. It is believed that lower quantities of chemicals will be satisfactory, but time was not available to determine the minimum quantity practical.

### Sugar-End Operation

The D-I thin juice was free from scale-forming substances and evaporation station performed very satisfactorily. In fact, the juice removed

scale from heating surfaces and pipe lines. It, in all probability, dissolved some scale, but it also loosened scale which appeared in the pipe lines.

The juice darkened upon concentration in the evaporators. However, the color was still very light. The thick juice had a very bland taste and was free of the characteristic beet taste or odor.

There were problems encountered in the sugar boiling that, although forseen, were not as easily solved as would be expected. The high-purity juices with small percentages of invert were foreign to normal beet factory experience and, as a result, the art of the sugar boiler required adaptation to meet the demands of a new type juice.

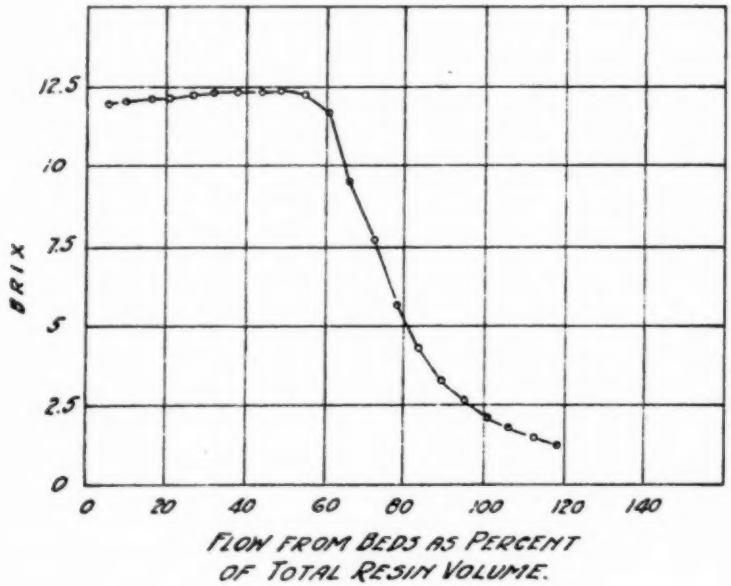



FIG. 2.—SWEETENING-OFF.

There were not any pronounced difficulties with the white sugar boiling. The pans grained well and the massecuites spun well in the centrifugals. The juice darkened considerably during boiling and molasses off the final pan was very dark.

During the period, it was not possible to produce a satisfactory white sugar off the second boiling of the green syrup from the first boiling. The sugar produced from this second boiling was much lower in ash than the regular run beet sugar, but it had a very slight yellowish color and was deemed unsuitable for marketing. It was remelted together with the other remelt sugars and reboiled.

There were some difficulties experienced with graining on the lower-purity pans. The increase in the rates of invert to sucrose was thought to partially account for this. The different viscosities of the juice effected the sugar boiler's judgment, which is based upon experience with normal beet juice.

A five-boiling system was attempted with the last pan of such a purity that it would yield 60-purity molasses. Part of the time this was realized. However, frequently, a pan did not yield as well as it should have, and the green purities from it were high. This entailed extra boiling, and a six-boiling system was used part of the time to correct this.

The lack of pan storage for the many liquors was a handicap in adhering to a boiling system. This is being studied for improvement of this phase in the future.

### Sugar and Molasses Produced

The sugar produced was of superior quality. The ash content of the sugar was very low. By conductance measurements, it varied from 0.0001 to 0.0020 percent with an average for the period of 0.0008 percent. The $SO_2$ content averaged 0.3 ppm. There was a marked improvement in candy grade and a rise in darkening temperature during the candy test. The sugar has a fine appearance and compares favorably or is superior to sugar normally produced in a milk of lime sugar factory.

The quality of molasses produced varied. This was probably due to inexperience with the new type syrups. The apparent purities sometimes rose appreciably above 60. The molasses had none of the characteristic odor or flavor of beet molasses. It did have a rather strong flavor characteristic of a very strong caramel or burnt-sugar taste. It was low in ash and high in invert, running from 8 to 16 percent invert on dry substance.

### Conclusions

It is difficult to draw satisfactory conclusions because the run was short and because the beets, during the period of operation at the end of campaign, were storage beets and in relatively poor condition. All the data has not been analyzed and full results and conclusions are not yet drawn. However, it can be concluded that

1. Ion exchange produces a superior sugar.

2. Final molasses purities below 60 are obtainable with proper boiling techniques.

3. Ion exchange, on these particular beets, can be operated with a chemical consumption of 25 pounds of 93-percent sulfuric acid and 6 pounds of anhydrous ammonia per ton of beets to produce satisfactory results.

# Non-Sugars in Beet Juices Removable by Ion Exchange

E. B. Fitch and J. W. Michener

The actual introducing of ion exchange into sugar beet processing brings compelling reasons for further studying and indentifying the non-sugars present in the juices. The potency of ion exchange for purifying sugar beet juice has been appreciated for several years. However, far less is known concerning what compounds constitute the non-sugars and how these behave individually in relation to ion-exchange columns.

More knowledge concerning the nature and ion-exchange behavior of non-sugars would be helpful in integrating the process of an ion-exchange unit to the sugar factory as a whole. That is, while an ion-exchange station itself can now be engineered with confidence, just how a factory should be operated to make the *most* of this revolutionary process is something which remains to be settled.

There is also another, and perhaps even more attractive reason for identifying and studying the non-sugars removable by ion-exchange. Several of these impurities, although most noxious if left in the juice, are capable of becoming valuable and profit-increasing by-products when isolated. Ion-exchange can offer some of them in a highly segregated form, separated cleanly from the sugars which constitute the bulk of the solids in the juice, and in such condition that further by-product purification is relatively simple.

Information given by ordinary sugar juice analyses is not suitable for predicting de-ionization behavior, and is not detailed enough to be of much value in surveying the by-product possibilities. Also, since juices vary from locality to locality, from season to season, and from day to day, a great number of juices must be analyzed before any generalizations can be made. In our early investigations of by-product possibilities, samples from but a few sources were used. In order to broaden the information on the composition of non-sugars, thick juice samples were requested this season from factories in various beet sugar districts of the country, thick juice samples being chosen because of their high concentration and keeping qualities. Sufficient data were also requested to permit working the thick juice analyses back to beets. The samples kindly supplied from the various factories are now being analyzed in The Dorr Company's Westport Laboratories. The analyses are far from complete, but the data collected thus far are here presented, in the nature of a progress report.

Previous work in our laboratory has shown that with a thoroughly regenerated cation bed (upflow, 900 percent HCL) ionized ash is 99.9 percent removed up to a certain percentage of the total capacity of the bed.

Simple amino acids, including betaine, are just as completely removed, however, to a somewhat lower percentage of the total capacity of the bed.

Therefore, if a volume of feed is chosen which is insufficient to give an amino acid breakthrough, any nitrogen leakage from the cation bed is almost assuredly other than simple amino acids. Thus both ash cations and simple amino acids are collected by the cation cell, and may be recovered from it for analysis.

The cation bed can also remove some peptides, but capacity for these decreases rapidly as they become more complex, and in tests on soluble peptide mixtures, 100 percent removal was not obtained even at the very start of a cycle.

A fully regenerated anion exchange resin can now remove from the decationized sample essentially all anions whose acids have an ionization constant greater than about $10^{-7}$, the capacity of the resin being the greater for anions of the stronger acids. This category includes the mineral acid anions such as $SO_4^-$, $Cl^-$, $NO_3^-$ and $NO_2^-$, and also apparently most of the organic non-sugars which had not been taken out in the cation cell. In fact more than half of the anions present in the beet sugar juices we have tested seem to correspond to organic acids with an average pKa in the range of 5 to 3.

Nitrogen compounds which are not removed from solution upon passing through the cation cell either must have no appreciable basic properties at all, or else like peptides must be tied up in molecules too large to diffuse into the cation resin structure with appreciable rapidity. Examples of such compounds are pyrrolidone carboxylic acid, browning reaction products, nitrates or nitrites, polypeptides, and perhaps also some nitrogenous organic compounds with neither acid nor basic properties.

Of these, pyrrolidone carboxylic acid has appeared to be the principle constituent, and tests have shown it to be removed quantitatively by the anion cell. Browning reaction products also must be completely absorbed, because the final effluent juice has been absolutely colorless. Inorganic nitrate and nitrite would be picked up, if present, but would not show up in our work because they are excluded by the Kjeldahl method used for nitrogen analysis. On the other hand, part of the peptides passing the cation cell would most probably also pass unabsorbed through the anion cell, and indeed, it would seem logical to guess that most of the nitrogen passing into the anion effluent will be in this form.

After passing the juice sample through a pair of exchanger columns, then, the ash cations, simple amino acids, some peptides and nitrogenous organic bases such as betaine remain adsorbed on the cation exchanger. The anions of the juice, including certain nitrogenous compounds, remain adsorbed on the anion exchanger. The sugars themselves, together with other essentially non-ionizable compounds and extremely weak acids, escape into the effluent.

Further fractionations of the adsorbed impurities are now possible, most important being separate elution of the nitrogen compounds from the cation exchanger. As published by Freudenburg (1)[2], the nitrogen compounds may be eluted by means of a weak base, such as pyridine or ammonium hydroxide. Weak alkali unloading of a cation exchange column also causes some downward displacement of the adsorbed ash in the column, but if part of the column at the downstream end has remained free of ash cations up to the start of unloading operations, then ash is displaced into this portion of the column, and does not escape into the effluent with the nitrogen.

In brief outline then, the procedures used for preliminary separation of the constituents of juice comprise the following steps: First the capacity of the cation resin with respect to the juice in question is determined in a 100 cc. column. Then a quantity of diluted juice calculated as insufficient to exhaust the exchangers is passed in series through one-liter beds of thoroughly regenerated cation and anion resins. With the effluent is collected the water from both sweetening-on and a substantial sweetening-off rinse. Analyses are made on feed and effluent juice samples without delay, in order to avoid spoilage.

Next, amino acids and related nitrogenous materials are eluted or "unloaded" from the cation bed by passing through it 9 liters of one normal ammonia solution followed by 1 liter of de-ionized rinse water, all at fixed low feed rate. The unloading effluent is boiled down to a small volume, made strongly ammoniacal to prevent spoiling, and is stored for subsequent analyses.

The cation cell after unloading is regenerated upflow with 9 liters of one normal hydrochloric acid, followed by 1 liter of rinse water. The spent regenerant is concentrated and stored for analysis.

The anion cell is regenerated with 3 liters of one normal ammonia solution followed by 1 liter of rinse water. This spent regenerant also is concentrated, made strongly ammonical, and stored for analysis.

The affect of this procedure upon the juice samples is shown in part by table 1. As will be seen, the apparent purities are increased by de-ionization to above 99 percent, at which level the exact significance of apparent purity becomes questionable. Nitrogen removals of 94 percent and up were obtained. Ash was not determined on the treated juice, but from flame photometer analyses, the removal of sodium plus potassium was in the range of 99.9 percent. In addition, there was essentially 100 percent removal of color in all cases; the effluent juices being water white.

It may be asked why the purification obtained in treating these samples is greater than that realized in existing commercial operations. The answer lies in the thoroughness with which the beds are regenerated. The relationship between the removal of impurities and regeneration has been previously reported by Thompson and Roberts (3). It will be sufficient

[2]The numbers in parentheses refer to literature cited.

here to recount that it is not considered economical to regenerate for such high removals in commercial operation, particularly so, when using conventional downflow regeneration.

In the course of the above described ion-exchange separations, certain resin capacity figures were collected. These include values for the total removable ash cations in the juices, the total anions to be removed, and an actual measurement of the amounts of juice which could be treated per cycle by a cation exchange column.

**Table 1.**—Ash and nitrogen removals from thick juice samples.

| Factory location | Sample taken | Ash content % in D.S. | Apparent Purities Sample | Apparent Purities DI Effluent | Nitrogen in sample % $N_2$ on D.S. | % Removal of nitrogen |
|---|---|---|---|---|---|---|
| A California | Early | 3.4 | 88.0 | 99.7 | 0.473 | 96.5 |
| | Mid-campaign | 4.2 | 90.0 | 99.1 | | |
| B Washington | Early | 2.7 | 93.0 | 99.1 | 0.295 | 96.9 |
| | Mid-campaign | 1.94 | 95.8 | 99.6 | 0.405 | 95.8 |
| C. Ohio | Early | 3.58 | 91.4 | 99.4 | 0.348 | 94.6 |
| D Montana | Early | 2.85 | 92.5 | 99.5 | 0.490 | 98.0 |
| E Colorado | Early | 2.72 | 93.4 | 99.5 | 0.134 | 94.6 |
| F Montana | Mid-campaign | 3.4 | 94.0 | 99.8 | | |

The total normality of the anions in a juice sample is obtained fairly directly by an ion-exchange technique. The juice, diluted to some suitable brix, if necessary, is passed through a thoroughly regenerated column of hydrogen exchange resin, whereby cations are replaced in the juice by hydrogen, and acids corresponding to the anions are created in the effluent. Successive samples of the effluent are titrated up to pH 7 until a constant titration for successive samples indicates that the column has been fully sweetened-on. Since some $CO_2$ may be lost from the acid effluent, if present, $CO_2$-free air should be blown through the effluent samples before titration to eliminate all of it. The value of the constant titration found shows the normality of the anions in the juice and is commonly termed cation acidity.

A second aliquot of the samples is titrated to pH 7, at which point most of the amino acids present will be in their iso-electric form. That is, they will be present in neither a cationic nor an anionic form. This gives the original alkalinity (or acidity) of the juice. The aliquot is then titrated on down to some low pH, the $CO_2$ blown off, and the sample titrated back to pH 7. The difference in titrations gives a value for the bicarbonate which was present in the juice at pH 7.

The normality of the total cations originally present in the sample is taken as the sum of the cation acidity, the original alkalinity, and the bicarbonate normality. The value will, of course, be in error if any amino acids were originally present which were not in their iso-electric form at pH 7, by whatever amount they affected the original alkalinity titration.

Table 2 shows the results of such determinations. In order to relate the original alkalinity, cation acidity, and bicarbonate normality to dry

solids, each was expressed in terms of equivalents per 1,000 grams of dry solids. This is a convenient form for the data, because when such figures are multiplied by the percentage solids in the juice (or brix) and the specific gravity of the juice, the result comes out directly in normality.

**Table 2.—Cation exchange data. (Equivalents per 1,000 grams dry substance.)**

| Factory | Sample taken | Apparent purity | Alkalinity | Cation acidity | $CO_2$ | Removable cations | Cation cycle[1] Bed volumes 10 bx juice | Cation Cell Ash loading Megs/cc Exchanger |
|---|---|---|---|---|---|---|---|---|
| A | Early | 88.0 | 0.016 | 0.538 | ---- | 0.55 | 13[2] | 0.71[2] |
| | Midseason | 90.0 | 0.022 | 0.54 | 0.021 | 0.58 | 6 | 0.32 |
| B | Early | 93.0 | 0.015 | 0.261 | ---- | 0.28 | 18[2] | 0.51[2] |
| | Midseason | 95.8 | 0.009 | 0.313 | Trace | 0.32 | 7 | 0.22 |
| C | Early | 91.4 | 0.117 | 0.435 | 0.002 | 0.55 | 9 | 0.48 |
| | Midseason | | 0.123 | 0.287 | 0.017 | 0.43 | 8 | 0.33 |
| D | Early | 92.5 | 0.01 | 0.423 | 0.01 | 0.42 | 9 | 0.36 |
| E | Early | 93.4 | 0.015 | 0.438 | 0.004 | 0.46 | 10 | 0.45 |
| F | Early | 94.0 | 0.031 | 0.397 | 0.003 | --- | -- | --- |
| | Midseason | | 0.028 | 0.414 | 0.002 | 0.44 | 10 | 0.43 |
| G | Early | | 0.004 | 0.376 | ---- | 0.38 | 8 | 0.29 |
| | Midseason | | 0.005 | 0.342 | ---- | 0.35 | 11 | 0.58 |

[1]Cation cycle represents the volume of sample diluted to 10 brix which can be fed to a cation exchange column before there is a pH breakdown in the effluent. Samples were fed through a 100 cc. column at 20 cc. per minute with the exception of those marked [2], which were fed at very low rates.

The cation cycle data shown in table 2 were obtained by feeding samples, diluted to about 10 brix, through a 100 cc. column of C-3 exchanger. In all cases but two, the rate of feed was 20 cc. per minute. The effluent from the column was collected in 100 cc. portions, pH and acidity titration determined on each sample, until an upward break in the pH indicated that buffering bases were starting to leak through the column. In table 2 is recorded the nearest whole number of samples of juice which could be collected before pH break-through after correcting the data to the basis of a 10 brix feed.

The ash cation content of columns at the end of each test cycle was determined from the quantity of juice samples which could be handled per cycle, corrected for the water originally present in the voids of the exchanger columns, and from the value determined for removable cations. As seen in the final column of table 2, the value varies widely even if the two slow run values are disregarded. While the capacity data was not taken with great precision, still the wide variation in net ash capacity of the bed to pH breakthrough indicates that the value for removable ash cations in a juice does not constitute in itself an accurate basis for calculating the amount of juice which can be treated per cycle. Also, since most of the values obtained are much lower than analogous values obtained in the de-ionization of water, it appears that a substantial portion of the cation cell capacity is being here employed to remove nitrogenous materials.

When nitrogen has been determined on more of the cation unloading samples, it will be interesting to see what sort of correlation can be worked

out between actual measured cycle length on one hand, and some combination of removable ash cation and nitrogen on the other hand.

Thus far, we have dealt with the purification of the juice effected by the de-ionization treatment, and the relationship, or lack of it, between certain juice titrations and the cation cycle length. Now we will return to the impurities which we left adsorbed on the cation cell.

As has been stated, the nitrogenous compounds are selectively eluted from the cation exchanger by means of an ammonia solution. This produces an effluent which we call amino liquor.

The unloading procedure used makes a fairly sharp separation between the ash and the nitrogen. For example, the total of sodium plus potassium contained in the amino liquor amounts to less than ten parts per million, on an original thick juice basis, while the corresponding concentration in the spent acid regenerant is of the order of magnitude of ten thousand ppm. The discrimination in the case of nitrogen compounds is not so sharp, but is still quite satisfactory, as shown in table 3. This gives the overall organic nitrogen balance obtained from two juices for which the necessary analyses have been completed. All values are expressed in terms of normality in the original thick juice samples. Ammoniacal nitrogen was expelled from all samples before analysis.

**Table 3.—Nitrogen balance.**

| | Factory A | Percent | Factory B | Percent |
|---|---|---|---|---|
| Nitrogen in amino liquor | .170 equivs/liter | 61.1 | .104 equivs/liter | 58.4 |
| Nitrogen in spent cation regenerant | .004 equivs/liter | 1.4 | .004 equivs/liter | 2.2 |
| Nitrogen in spent anion regenerant | .089 equivs/liter | 32.0 | .062 equivs/liter | 34.8 |
| | .273 | 98.1 | .176 | 98.5 |
| Nitrogen in original juice | .278 | | .178 | |

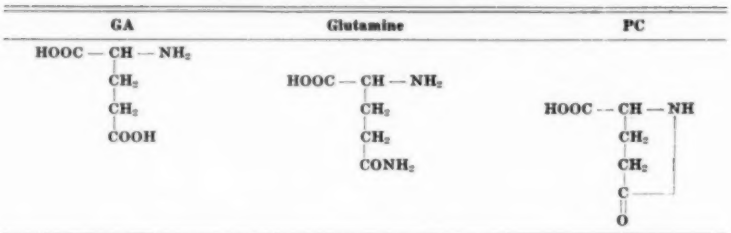
It can be seen that in the case of Factory B only about 4 percent of the nitrogen removed from the cation cell went with the acid regenerant, and in the case of Factory A, the fraction was substantially less. It is also apparent that a large fraction of the nitrogen is in anionic form.

The nitrogen compounds are prime candidates for by-product recovery. One of them, namely glutamic acid, is already being recovered from Steffens filtrate, and a large market has been developed for it. Thus, at this time, we are most interested in the content and distribution of glutamic materials in the juices.

The glutamic acid picture is complicated by the fact that potential glutamic acid may exist in three different forms in the juice, namely, as glutamic acid, glutamine and pyrrolidone carboxylic acid. In order to spare our tongues and save time, we use the abbreviations GA and PC for glutamic and pyrrolidone carboxylic acid, respectively.

Figure 1 shows the structure of these compounds.

**Figure 1.—Potential glutamic compounds.**




As will be seen, glutamic acid has both an acid carboxyl group and a basic amino group attached to the top carbon atom. Through zwitterion formation, the acid and basic strengths of these two groups tend more or less to cancel or mask each other.

As a result, the top group does not have sufficient residual acid strength to permit adsorption on an anion exchange resin through this group. The residual basic strength is, however, still sufficient to permit basic ionization and adsorption in a cation exchanger. Also, there is another carboxyl group in the bottom, or distal position, which is not appreciably weakened by the alpha amino group, and through which the molecule may be held on an anion exchanger. Thus, GA itself can be held on either a cation exchanger or on an anion exchanger.

In glutamine, on the other hand, the distal group is an acid amide, with insufficient acid strength to permit adsorption in an anion exchanger. Therefore, glutamine is held by a cation exchanger only.

In PC the distal group has swung around and reacted with the amino group. The basic properties exhibited by the amino group are neutralized, and PC is not adsorbed in a cation exchanger. At the same time, the latent acidity of the alpha carboxyl group is unmasked, and the molecule can be adsorbed in an anion exchanger through this group.

Thus, if we pass a mixture containing all three compounds through a pair of exchange cells, the GA and glutamine will stop in the cation exchanger, while PC will pass through the cation cell to be caught in the anion exchanger.

Glutamine is very unstable, and converts easily to PC upon heating to boiling. There is an equilibrium between PC and glutamic acid, which has been reported in considerable detail by Wilson and Cannon (2). At very high or very low pH's, the equilibrium is shifted far in favor of GA. In the intermediate range the equilibrium favors PC, but between about pH 4 and pH 10, the conversion reaction velocities are too slow to be of much help in either analytical or process work. Use is made of both conversion and ion-exchanger behavior in the analytical methods used.

Analysis for glutamic compounds has been carried through on only two of the amino liquors to date. This is done by autoclaving samples which have been adjusted to an initial pH of 3.2 for 6 hours at 20 pounds

steam pressure, which breaks down all the glutamine present and would give at equilibrium something like 94 percent PC and 6 percent GA. The autoclaved sample is passed through a cation exchange column to remove all nitrogen compounds but the PC. The effluent is then analyzed for nitrogen. As a check, a portion of the effluent is hydrolyzed with HCl to convert the PC back to GA, and a formol titration made on the hydrolysate. The results so far obtained are as follows: The glutamine plus GA in

Factory A=.023 normal in thick juice
Factory F=.009 normal in thick juice.

Actually, all these two figures amount to is sort of a teaser. No conclusions can be drawn until many of the stored amino liquors are analyzed in much greater detail. This will be done during the coming months.

With respect to the potential glutamic acid in the juice, however, it may be said that whatever portion of it is collected on the cation exchanger can be isolated and recovered fairly simply. Recovery of glutamic acid from the PC picked up on the anion exchanger has not been found so expedient.

Another consideration concerning nitrogen compounds is as follows: If the ammoniacal spent regenerants from a D-1 house are used as fertilizer, which seems a promising prospect, then it is probable that the relative amino acid content of the beets so fertilized will increase. This would be disadvantageous if nitrogen compounds were not being recovered, but might be very attractive if they constituted a valuable by-product.

Returning now to the original analytical separations, it will be remembered that after the nitrogen compounds are unloaded from the cation cell, it is regenerated. The spent regenerants are being analyzed for the most important cationic ash constituents, and the available results are shown in table 4. Here sodium and potassium are analyzed in a flame photometer, while Ca and Mg are analyzed by standard methods.

**Table 4.—Ash constituents.**

| Factory | Sample taken | Equivalents per 1,000 grams dry solids | | | |
|---|---|---|---|---|---|
| | | Na | K | Ca | Mg |
| A | Early | 0.15 | 0.26 | 0.02 | 0.002 |
| | Mid-campaign | 0.23 | 0.26 | ---- | ---- |
| B | Early | 0.045 | 0.24 | 0.029 | 0.0016 |
| | Mid-campaign | 0.058 | 0.24 | 0.029 | 0.0025 |
| C | Early | 0.25 | 0.34 | 0.005 | 0.0007 |
| D | Early | 0.094 | 0.37 | 0.041 | ---- |
| E | Early | 0.140 | 0.370 | 0.062 | ---- |
| F | Mid-campaign | 0.183 | 0.388 | 0.097 | ---- |
| G | Early | 0.083 | 0.230 | 0.017 | 0.0001 |

We have done very little work as yet with the spent anion regenerant from the series of thick juice samples. However, using canned first fill-mass as a working material, we found in the past that over 90 percent of the anionic nitrogen adsorbed in that case would be recovered as alpha amino nitrogen by acid hydrolysis, and presumably was PC although

that will require further checking. Anions adsorbed from this material have been fractioned chromatographically in ion-exchange resins, to yield weak acid fractions containing substantially more than half the total anions originally present in the juice. It is hoped that among these weak acids can be identified further compounds with by-product possibilities.

Grateful acknowledgment is due to the sugar companies who supplied samples, and to J. Sheehan of The Westport Laboratory Staff, who is carrying out the ion-exchange separation of samples described in this paper.

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# Comments on Use of Ion-Exchange Resins in Demineralizing Sugar Beet Juices[1]

C. A. Fort[2]

THE PARTICULAR points to which your attention will be called are 1. the effect of the concentration of minerals in the beets on the cost of ion-exchange operation and 2. the effect of the composition of the sugar beet minerals on the amount of the additional sugar recovered.

We have made extensive studies of the final molasses from nearly all of the non-Steffen factories of the domestic industry. Taking into account the molasses produced, calculated as percentage on weight of beets, it is evident that the composite beet processed at some factories contains double the concentration of mineral ions that occur in the beets at other locations. At a particular factory the differences between beets from various fields serving the factory may show equal or even greater variation in mineral content. This latter fact is not so important from the viewpoint of the use of ion exchange for demineralization where we are only concerned with the average mineral content of the total crop. In addition to the contrasting total amounts of mineral ions in the beets, there is also a very considerable variation in the proportional amounts of the individual mineral constituents. These conditions have a decided effect on the economic balance obtainable in the use of ion exchangers.

From the known chemistry of ion exchangers it is an accepted fact that a given amount of resin will remove only a definite number of either basic or acidic ions according to the type of resin. Further, for regeneration of the resins, a chemically equivalent amount of regenerant chemical must be used plus a certain excess. It is, therefore, evident that for beets with a high content of mineral ions that the length of cycle that a resin can be used before exhaustion will be relatively shorter and the amount of regenerants required per ton of beets processed will be much greater than when the beets are low in minerals.

The range of diffusable sulphated ash content in beets is roughly from 0.4 percent to 0.8 percent on weight of beets. This means that for factories with the lowest ash beets the minerals to be removed from diffusion juice are of the order of 8 pounds per ton. However, for those in the high-ash bracket, the removal must approximate 16 pounds of minerals per ton of beets. For evaluation purposes the determination of sulphated ash is the best of the simple methods; it has the advantage over carbonate ash in that at least the acid radical part of the ash is uniform. Even fully sulphated ash does not represent an entirely accurate measure of ionizable minerals since the composition of the basic portion is still variable. Sufficient accu-

[1]Agricultural Chemical Research Division Contribution No. 226.

[2]Chemist, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

racy for preliminary predictions is obtainable by assuming that the average combining weight of the metallic base is 31 in raw diffusion juice and 35 in clarified or thin juice. This assumption of a lower combining weight in the raw juice is due to the presence therein of fair quantities of magnesium. This metal is practically eliminated in the carbonation process, and lime is also brought to a low concentration, with the result that in thin juice the ratio of potassium to sodium governs the mean combining weight.

To estimate the work that the ion exchangers must do and the amount of regenerants required, we can proceed on the basis of chemical calculations. For example, a pound of sulphated ash with a combining weight of 31 for the metallic bases is equivalent to 5.74 normal weights of both basic and of acidic ions. With 35 as the basic combining weight the equivalent is slightly less, 5.47 normal weights. It is recognized that in the case of the raw juice the basic ions (which determine the amount of sulphated ash obtained) are very slightly less than the acid radicals to be removed. For the thin juice the opposite prevails, that is, the basic portion is greater so that the cation exchanger has more work to do than the anion exchanger, and the sulphated ash value agrees best with the work done by the cation exchanger. For the extremes of diffusable sulphated ash already mentioned (0.4 to 0.8 percent on weight of beets) the corresponding normal weights of minerals to be exchanged per ton of beets would be approximately 44 and 88.

Now what do these facts mean in terms of capacity of exchanger needed per ton of beets and in terms of regeneration chemicals per ton of beets?

We will assume an exchange capacity of 17.5 normal weights per cubic foot of resin in the column. The actual capacity may be higher or lower than this depending not only on the quality of the resin but also on its tendency to compact in the column. For beets that contain about 0.4 percent diffusable sulphated ash or 44 normal weights per ton, this means that approximately 2.5 cubic feet of exchanger will be needed per ton. At the other extreme of high-ash beets (0.8 percent) the capacity needed would be 5.0 cubic feet per ton of beets. For most factories the requirement would be intermediate and will be dependent on the diffusable ash concentration of the average beet for that particular factory and season.

It may also be stated that if the maximum removal of ionized nitrogen compounds is desired, the exchanger capacity required per ton of beets will exceed the amount indicated by the ash content. This is due to the ease with which such compounds are displaced from the exchangers. Hence, at some locations where relatively high concentrations of nitrogen occur in the beets, the exchanger capacity needed will correspond to a high-ash content, but the regenerant chemicals required would still be governed by the actual ash content of the beets.

For the alkali regeneration of the anion exchanger it will be assumed that 1.1 times the chemical equivalent will suffice and that for the cation

exchanger 1.3 times the theoretical quantity of the acid will be needed. (In practice the efficiency in the use of regenerant chemicals is usually much less than indicated by this example.) For the anion regeneration per ton of low-ash beets (0.4 percent), the amount of alkali required will be 44x1.1 or 48.4 normal weights. In the case of high-ash beets (0.8 percent) the amount of alkali required would be doubled or 96.8 normal weights. For the cation regeneration the amount of acid required per ton of low-ash beets (0.4 percent) would be 44x1.3 or 57.2 normal weights, while in the case of high-ash beets (0.8 percent) the amount would be 114.4 normal weights. What this means in terms of weights of chemicals is shown in table 1.

**Table 1.—Weights of regenerant chemicals per ton of beets.**

| Reagent | Chemically pure reagent | | Commercial-grade reagent | | |
|---|---|---|---|---|---|
| | Low-ash beets (pounds) | High-ash beets (pounds) | Quality grade (percent) | Low-ash beets (pounds) | High-ash beets (pounds) |
| Caustic soda ($NaOH$) | 4.26 | 8.52 | 76 | 4.35 | 8.69 |
| Soda ash ($Na_2CO_3$) | 5.65 | 11.30 | 58 | 5.70 | 11.40 |
| Ammonia ($NH_3$) | 1.81 | 3.62 | liquid | 1.81 | 3.62 |
| Sulphuric acid ($H_2SO_4$) | 6.23 | 12.46 | 66° Be′ | 6.69 | 13.38 |
| Hydrochloric acid ($HCl$) | 4.60 | 9.20 | 22° Be′ | 12.78 | 25.56 |

If ionizable minerals were the only melassigenic non-sugars in beet juice and if the total concentration of minerals were directly related to the amount of sugar normally left in molasses, then the exchange capacity and the weight of regenerants required would be directly correlated with the additional sugar made recoverable. In other words, the cost per unit of additional sugar recovered would be uniform irrespective of the ash content. But this is not the actual situation. There are colloidal and organic non-sugars which are not removed by the ion exchangers, and, further, the amount of sugar normally lost in molasses is not directly correlated with total minerals. That is, a factory with a high-ash beet may obtain better sugar extraction than another factory with a low-ash beet. This may be partly due to non-ash melassigenic constituents and in part to operating care, but from studies of molasses composition in relation to sucrose lost in molasses calculated as percentage on weight of beets, it is also evident that the relative amounts of the different mineral constituents are also a factor. Metallo-organic salts form a variable but usually large proportion of what we are here calling mineral content. These organic salts appear to be much more melassigenic than any of the strictly mineral salts such as sulphates, sulphites, or chlorides. The only exception is when chlorides are very high and sulphates low. Hence, for a given total concentration of ions when the proportion of mineral acid radicals is high, a relatively small amount of sugar is lost to molasses as compared with the situation when the proportion of organic acid radicals is high. As a matter of record, six factories with beets of essentially the same total ash content show a variation from 2.1 percent to 2.6 percent in sugar loss in

molasses calculated as percentage on weight of beets. Hence, while the cost of using ion-exchange demineralization would be equal at all six factories, the additional sugar recovered would not be the same.

Therefore, the general conclusion is that when the sugar loss is high in relation to the ash concentration in the beets then ion exchange has a better chance to be profitable. When, however, the mineral content is high mainly due to strictly inorganic salts, then with a smaller amount of sugar to be made recoverable by the process, the cost will be much harder to justify. Further, under this condition of higher proportions of strictly inorganic salts, it is likely that losses through inversion during demineralization will be greater than when organic salts predominate. This would be due to the greater inverting power of sulfuric and hydrochloric acids over that of the weaker organic acids, such as the amino and sugar acids. It can also be mentioned that the application of ion exchange to raw diffusion juice should produce a greater tendency to inversion because the liberated phosphoric and oxalic acids are stronger than the sugar acids which appear to replace them in thin juice.

By way of summary the following points will be restated:

1.—Independent of the unit capacity of the exchange resins the total ionic capacity required per ton of beets will be directly related to the total mineral ions per ton of beets. Between different factories this mineral content is widely variable and some factories may need double the exchange capacity per ton of beets that is needed at another location.

2.—The weights of regenerant chemicals needed will be variable to exactly the same degree as the exchanger capacity.

3.—While, for a particular mineral content in beets the exchange capacity and quantity of regenerant chemicals are fixed, the additional amounts of sugar made recoverable by the process will be variable between different factories. This is due to the differing compositions of the mineral constituents which affect the amounts of sugar normally lost to molasses.

4.—The fully sulphated ash determined on diffusion juice or thin juice calculated as percentage on weight of beets gives a reasonably accurate basis for estimating exchange capacity and weight of regenerant chemicals required per ton of beets.

# Tetraphospho Glucosate as a Scale Inhibitor

SOMERS MOORE[1]

GLUCOSIDES and their derivative glucosates and similar preparations have been widely recommended by their manufacturers as scale inhibitors for sugar factory evaporators. Favorable results have been reported for the use of tetraphospho glucosate in a raw cane sugar mill[2] and a refinery.[3]

It was our purpose to test the efficiency of these compounds in our high pressure, long tube vertical evaporators.

Scaling conditions at Woodland are very severe. During the 1946 campaign of 113 days, we had 35 evaporator boil-outs. Yearly average thin juice lime salts were 0.191 percent on R.D.S. During the 134 days of 1947 campaign with 0.203 lime salts we boiled-out 44 bodies. It is evident that the Woodland evaporators provide a severe test for a scale inhibitor and that an appreciable abatement of scaling would justify a considerable treatment cost.

## Experimental Procedure

In another paper on this program, Coons has described the design and operation of these evaporators. It is necessary here to point out only that the parallel bodies in first and second effect afford an unusually direct method of testing a scale inhibitor, since one side can be treated, and the other used as a control, and variation in the inherent scaling tendency of the feed can be disregarded. One need only compare the efficiency, expressed as an overall heat transfer coefficient, of the treated with the untreated side.

The heat transfer coefficients for the first bodies were calculated from the steam flow to the individual bodies, obtained from recording flow meters, the steam temperature and pressure, and the constant area of the heating surface. Juice flow to the individual first bodies was measured by installing an orifice in each feed line and measuring the pressure drop with a mercury manometer. From the above data and the R.D.S. of the feed to and discharge from each body, second body coefficients were calculated.

A run through four separate boil-out cycles was made with tetraphospho glucosate, two at 15 parts per million addition to the juice entering 1B and two at 7 parts per million. One test at 7 parts per million was made by treating 1B and one test by treating 1A to check the possibility that one body might have some inherent advantage.

Later a further test was conducted with a straight glucosidal preparation, free from phosphate.

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[1]Chief Chemist, Spreckels Sugar Company, Woodland, California.

[2]Hewlett Wulfekuhler and Lui: "Hawaiian Experience with Tetraphospho Glucosate for Preventing Scale in Evaporators". Sugar, 42, 4 April, 1947, pp. 30-31.

[3]Fitzwilliam and Yearwood "Use of Tetraphospho Glucosate as an Evaporator Scale Preventer". Sugar 42, 1 January, 1947, pp. 24-26.

## Experimental Results

Figure 1 shows the results of the first three runs with tetraphospho glucosate. The first set of curves shows the heat transfer coefficients for the period September 20 to September 30. Tetraphospho glucosate was added to 1B at the rate of 15 parts per million on juice. Inspection of the curves shows that near the end of the run the treated body was about 2½ days behind the untreated in loss of heat transfer efficiency. For the 10-day run this corresponds to a lengthening of the boil-out cycle of about 25 percent.

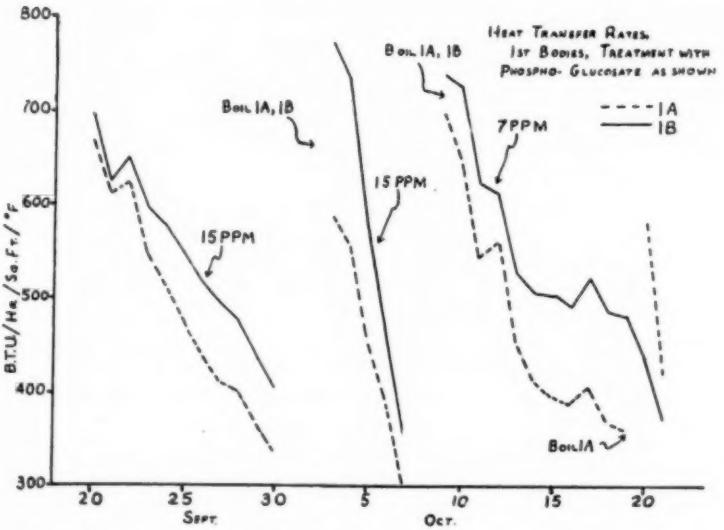



Figure 1.—Three tests with tetraphospho glucosate.

The second test, at the same addition rate, shows a lengthening of the boil-out cycle of the treated body of about 0.8 day in 5 or about 16 percent.

For the third and fourth runs the addition was reduced to 7 parts per million. The third test shows a lag in the treated body of almost 3 days in 10 or about 30 percent. Here we actually gained one boil-out as 1A was boiled on October 20. However, scaling conditions were so bad that both bodies had to be boiled 2 days later.

In figure 2, the fourth test with tetraphospho glucosate is shown. Addition was to the other first body, 1A, at a rate of 7 parts per million. Again the treated body shows an advantage of about 2 days in 10 or 20 percent.

No tests were made at higher addition rates, since we were approaching the economic limit, where the cost of treatment exceeded the cost of boiling-out. On the basis of these tests at 7 and 15 parts per million, we found a gain in the length of the boil-out cycle (or a reduction in boil-outs) of first effect evaporators, attributable to the treatment, of about 25 percent. No benefit in second effect was discernible.

At this point we dropped the testing of tetraphospho glucosate and began a test with a plain glucoside. We hoped to make a series of runs with this chemical; however, as shown in figure 3, the evaporators scaled very slowly during this period, and we were unable to complete our planned tests before the end of campaign. Day to day variations at this slow scaling rate make this curve extremely irregular, but a slow scaling tendency, which increases toward the end, can be observed. The trend is better shown in figure 4, by plotting the 3-day moving averages of the heat transfer coefficients.

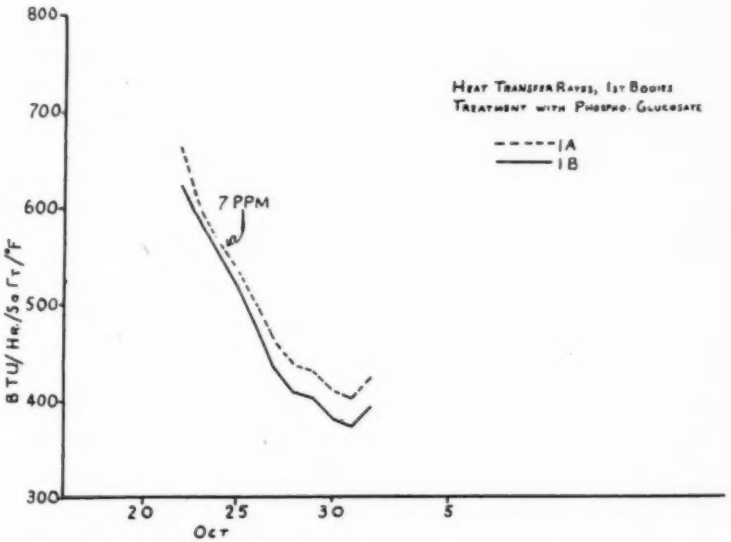



Figure 2.—Fourth test with tetraphospho glucosate.

Although there is undoubtedly some benefit to be attributed to the treatment, it is difficult to evaluate due to the slow and erratic progress of the scaling curves. An estimate can be made by treating the curves as linear and extrapolating to the minimum allowable heat transfer coefficient, which we consider to be about 300 B.T.U. per hour per square foot per degree Fahrenheit. By this method (for which no accuracy can be claimed), an apparent benefit of about 30 percent is found.

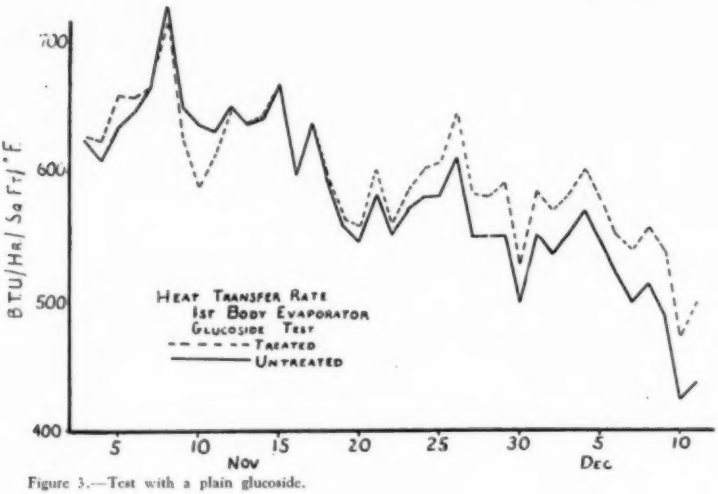



Figure 3.—Test with a plain glucoside.

## Effect of Sulfitation

The question arises: why did we run only 8 days between first body boil-outs at one period (October 2 to October 10) and later make an incomplete boil-out cycle of 38 days (November 2 to end of campaign)? A possible explanation lies in the effect of varying the sulfur dioxide addition.

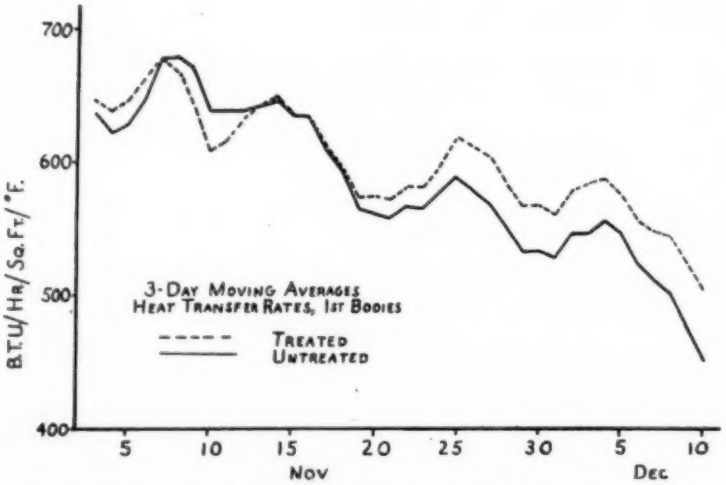



Figure 4.—Test with a plain glucoside. Three-day moving average to smooth curve.

Calcium sulfite is a compound of low solubility with an inverted solubility curve, typical of scale-forming compounds. If the sulfite concentration were kept low enough that the solution was under-saturated with respect to calcium sulfite, scaling from this cause would be eliminated.

By a coincidence, at the start of the last test, November 2, the sulfur addition was reduced to ½ the previous addition (0.18 pound per ton of beets to 0.08 pound per ton). This change was not thought of at the time in connection with evaporator scaling, but later as the evaporators continued to stay clean, the reduced sulfitation was advanced as an explanation.

To test this possibility, the sulfur dioxide addition was again raised on December 5, and the increased scaling after this date seems to provide some verification. We plan to continue this investigation.

## Summary

Controlled tests with the two inhibitors, tetraphospho glucosate and a glucoside, indicate partial (about 25 percent) benefits in first effect, and no discernible benefit in later effects. Since only 12 of our 44 boil-outs were of first bodies, this would save us only 3 boil-outs out of 44. The tests were made in the Woodland long tube vertical high-temperature evaporators, and the results probably are not directly applicable to beet sugar evaporators of conventional design.

# De-Ionization and Beet Sugar Production at the Layton Sugar Company

LYLE B. PORTER[1]

THE RECENT development of the resinous type ion-exchange materials and the stability of these resins to wide ranges of operating conditions has opened new fields to their application; not the least of these is in the field of sugar production.

After several years of investigational work in our own laboratories on this problem, it was felt that further work must of necessity be done as pilot-plant studies in the field. Accordingly arrangements were made with the Layton Sugar Company to conduct pilot-plant studies in their plant during the 1946 campaign. Results of these studies confirmed the laboratory findings and permitted the drawing of the following conclusions: 1. more high-purity sugar per ton of beets may be delivered to the bag with less reprocessing; 2. inversion can be held to a minimum if temperatures are properly adjusted; 3. the quantity of final molasses will be materially reduced, and what molasses there is will be an edible product; 4. the investment in full-sized equipment appears to be economically sound.

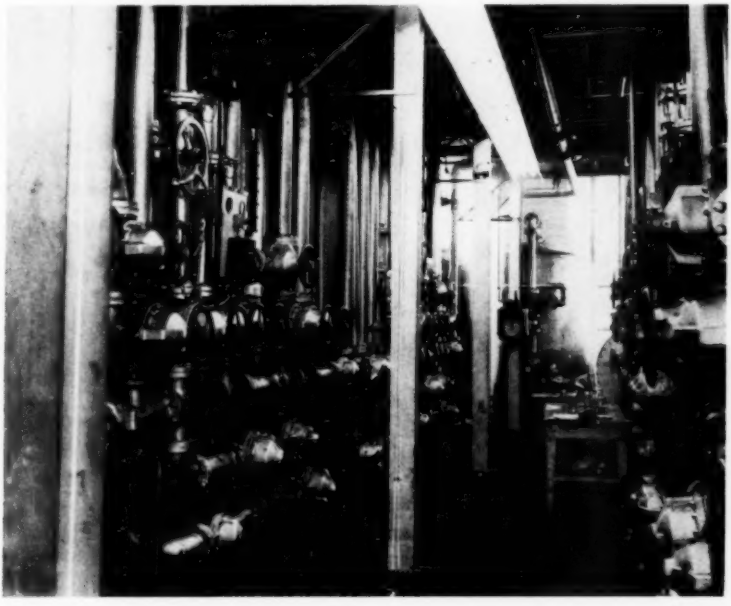
In view of the results obtained from this pilot-plant study the Layton Sugar Company contracted for an installation to treat their entire production of 1,350 tons daily capacity. Installation was to be completed in time for the 1947 campaign. When final arrangements were completed less than 6 months remained to complete the job of designing, fabrication and erection of the entire plant. Little wonder it was not completed when slicing operations started on October 7. The de-ionization plant operation started on October 22.

The de-ionization plant consisted of four units each unit being composed of a cation cell 10 feet by 14 feet containing approximately an 8-foot bed of resin and an anion cell 10 feet by 11 feet containing approximately a 5½-foot bed of resin. A valve assembly was provided on each unit, with adequate headers, to direct the flow of liquids during the various phases of operation. The valves are hand-operated, rubber-lined Saunders-type diaphragm valves. Common to all units is a set of regenerant tanks with automatic controls for refilling and diluting the regenerants. Pumps are provided for pumping the regenerants through the exchanger beds. Controls such as rate-of-flow indicators, conductivity meters, specific-gravity recorders, positive-displacement meters, recording thermometers, etc., were also provided. A duplex water softener was provided to supply soft water for diluting the ammonium hydroxide regenerant and for regenerating the acid-adsorber beds. This prevents the precipitation of magnesium hydroxide on the resin bed which would lengthen the regeneration period. All tanks,

[1]Director of Research, Illinois Water Treatment Company, Rockford, Illinois.

valves, piping, etc., that come in contact with acid, liquor and juices were rubber lined.

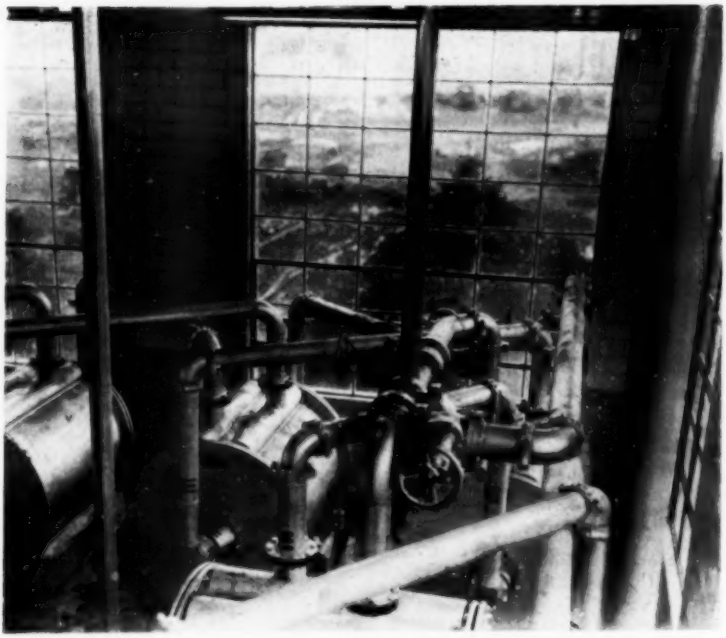
Bulk handling equipment for unloading and storing of carload lots of concentrated acid and ammonium hydroxide were a part of the installation.



Six spiral heat exchangers were installed to cool the incoming juice and reheat the treated juice.

The operation of this equipment was relatively simple. After approximately 1 weeks' training period one man and a helper per shift conveniently operated the station. In fact on occasions, one man operated the station alone.

During pilot-plant studies it was found that excessive inversion was experienced if the juice was passed through two units in series in order to remove the last traces of ionizable salts, therefore, the plant was designed for single pass operation. Each unit was designed to handle the entire plant production for at least 1¾ hours. This gave 5¼ hours from the time any unit was shut down till it was needed for service again. This procedure allowed more than sufficient time to regenerate each unit. Graph 1 shows the sequence of operation of the four units.



Second-carbonation juice was used as the raw supply to the de-ionization station. This juice first passed through the six heat exchangers, where it was cooled, and the treated juice reheated prior to passing on to the evaporators. It was hoped that the juice could be treated at a temperature of 50 degrees Fahrenheit or less, but the supply of cold water was somewhat limited and the temperature occasionally reached 60 degrees to 65 degrees Fahrenheit. There has been considerable discussion as to the possibility of treating raw diffusion juice in order to save the cost of liming and carbonation. There is always the question of removing the colloids from the raw juice and it is felt that possibly the lime is the cheapest filtering medium obtainable. A new approach to the problem of filtration has recently been presented, however, that may change this picture in the near future. More experimental data must be obtained before a definite answer can be given.

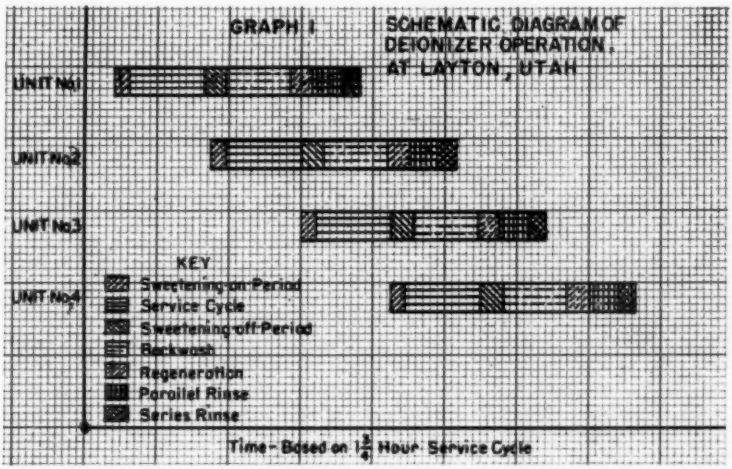
After passing through the ion-exchange process, the juice is practically water white, bland tasting and has completely lost that "beety" odor.

Needless to say, this high-purity juice created some operating problems in the factory, but since another paper is to be presented on this phase of the project, they will not be discussed at this time.

The complete cycle of operation of a unit consists of the following steps:

1. Sweetening-on.
2. Service.
3. Sweetening-off.
4. Regeneration.

At the start of the cycle the voids in the resin beds are full of water. As juice is started to the unit some 70 to 80 percent of this water is forced from the bed containing no sugar and may be discarded or returned to water reclaim. The remaining voids water becomes increasingly stronger in sugar content until the water is displaced and the juice passes through the unit at full sugar strength. This step is known as sweetening-on.




Normally the flow of juice is continued through the unit until there is evidence of the resins becoming exhausted. In this instance, an attempt was made to anticipate this break and start the sweetening-off step before the resins were exhausted so that all the juice in the unit could be forced ahead rather than recycled through a fresh unit. This procedure worked out very satisfactorily.

After the specified amount of juice had passed through the unit, a new unit was turned into service and water turned into the exhausted unit forcing out the remaining juice. Approximately 80 to 85 percent of this juice is forced out at full sugar content. The remaining juice is forced out at decreasing sugar content. When the sweet water is of such low

brix that it is no longer practical to evaporate the water for the small amount of sugar remaining, the water is turned to the sewer.

After sweetening-off the cation and anion resins are backwashed individually. This serves the dual purpose of first removing any colloidal matter or sediment that has collected in the beds during the service cycle and second to loosen and reclassify the beds. It has been found that definite advantages are to be had if this backwash is done with hot water. The hot water will more easily loosen and remove certain waxy and gelatinous materials found in the beds. By proper selection of resins this can be accomplished without detrimental effects on the life of the resins.

The resins are now ready for regeneration. The cation unit is regenerated with a 4 to 5-percent solution of sulfuric acid and the anion unit with a 5-percent solution of ammonium hydroxide. Each regeneration required 1,600 pounds of 66 degrees Be' acid, 1,095 pounds of anhydrous ammonia and approximately 100,000 gallons of water of which some 15-20,000 gallons may be recycled for a net water consumption of 80-85,000 gallons. Approximately 30 percent of the acid is reclaimed and used as the first acid on the next regeneration. The remaining acid regenerant and the ammonia solution is discharged to the sewer.

It is believed that the quantities of regenerants used were somewhat excessive and that a substantial reduction can be accomplished without impairing the efficiency of the operation. The urgency of other work prevented a detailed study of this point during the past campaign but it is hoped that a reduction of some 25 to 30 percent can be accomplished this next year.

Considerable work has been done in our laboratory on the problem of recovering valuable by-products from the spent regenerant solutions but more work must be done before a definite statement can be made. It is entirely within the scope of imagination, however, that the major part of the operating expenses may some day be carried by these by-products.

After the regenerants are introduced the beds are rinsed, first individually and finally in series, to remove the last traces of excess regenerants. The unit is now ready for another operating cycle.

From October 22 when the ion-exchange equipment went into service, it was in continuous operation to the end of the campaign on December 25, with the exception of approximately 36 hours of which the greater part was due to failure of the supply of ammonia and a relatively short shut-down for cleaning heat exchanger equipment. After approximately a month's operation a decrease was noted in the anion capacity. We were aware that the other plants had and were encountering the same difficulty but nonetheless we were disturbed. It should be pointed out that the difficulties were with a relatively low pH effluent but not with a low overall capacity of the resin for strong acids. Stopgap measures of correction were introduced but it was of the utmost importance to uncover proper permanent correctional procedures.

Such experiments were made as could be performed in the Sugar Company's laboratory to restore this capacity but they were only partially successful. It was, however, well demonstrated that the loss was not due to any destruction of the resin but rather to the cumulative effect of trace organic compounds in the beet juice irreversibly attaching themselves to the resin and masking its active groupings from the weaker organic acids. Later experiments with the greater facilities of our own laboratory have given every indication that treating the resin with a strong reducing agent removes these bodies, restoring it to its original capacity. This has been substantiated with test runs on Layton beet juice sent to our laboratory. Indications are that reoccurence of this loss in capacity can be prevented simply and inexpensively.

The question has frequently been raised as to the bacteria growth in the resin beds and their effect on sugar production. After the plant had been in operation some 6 weeks, samples of the resins and various juices and liquors were taken for bacterial study. The following table shows the results of these tests.

| | Flat Sours | Total thermophyles | Total bacteria @ 37° | Molds | Yeast spores |
|---|---|---|---|---|---|
| Cation resin end of run | ---- | Innumerable | Innumerable | 200 | -- |
| Anion resin end of run | 90 | 165 | Innumerable | 125 | -- |
| Treated juice first of run | | 5 | 620 | --- | -- |
| Treated juice end of run | ---- | ---- | 925 | --- | -- |
| Second carbonation influent to heat exchangers | 425 | 425 | 22500 | 10 | -- |
| Second carbonation effluent from heat exchangers | 2260 | 2260 | Innumerable | --- | -- |
| Cation backwash | 6250 | 6250 | Innumerable | --- | -- |
| Anion backwash | ---- | ---- | 210 | --- | -- |

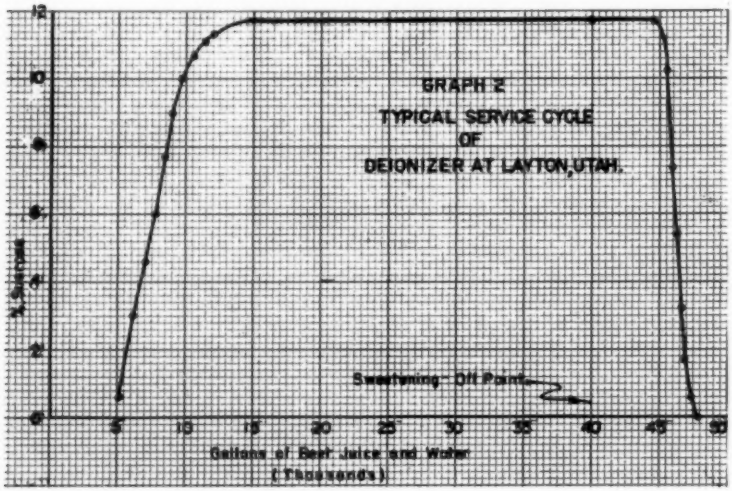
From the above, it is quite evident that while the juice was quite heavily contaminated entering the de-ionization equipment, it was relatively free of objectionable contamination leaving the equipment. Indications are, in this particular case at least, that the resin beds actually acted as a filtering medium to remove some bacteria as well as destroying other bacteria, and further that regeneration cleanses the beds of the accumulated bacteria.

Perhaps the best way to summarize the operation of the plant is to quote a few figures. The following are averages for the entire operating period and in most cases represents the results of several hundred determinations. Brix of influent juice 12.95; brix of effluent juice 11.81; percentage sugar influent juice 12.13; percentage sugar effluent juice 11.61; influent purity 93.76 percent; effluent purity 98.60 percent; pH influent 8.14; pH effluent 7.13; percentage invert influent .13; percentage invert effluent .39.

A study of the percentage sugar figures for influent and effluent juice indicates an overall dilution of 4.28 percent. Graph 2 shows a

typical sweetening-on—sweetening-off curve for this plant. It is interesting to note the extreme rapidity with which these steps were accomplished. At Layton, all juice above two brix was sent to the evaporators. Obviously, economics dictates the point to start saving the thin juice and the disposal to be made of the sweet water.

Undoubtedly the next question in your minds is that of sugar losses due to the de-ionization station. The unknown sugar losses at the Layton plant during the time the de-ionization equipment was operating were increased by .24 percent sugar on sugar.




The purity rise figures indicate a non-sugar removal of 77.56 percent. Previous reports of pilot-plant studies have frequently indicated considerably better results. However, the unusually high purity of the untreated juice must be taken into consideration in this case.

A favorable pH condition is indicated by the figures quoted. During the time we were experiencing the resin difficulties previously mentioned, it was necessary to occasionally adjust the pH of the evaporators by the addition of alkali. This required only small dosages, however, due to the unbuffered condition of the juice.

It is believed that the overall picture of .26 percent increase in inversion is quite favorable. However, a considerably lower figure had been expected. As previously indicated some difficulty was experienced with the cooling water supply. About 2 weeks before the end of the campaign, the cold surface water supply failed, necessitating the use of ground water,

having a temperature of 66 degrees Fahrenheit. A material increase in the invert was noted following this change.

Reports from the Layton Sugar Company show an extraction of 92.03 percent for the time the de-ionization equipment was in operation. This is a material increase over the approximately 85 percent to be expected on straight house operation, and as reported by Mr. Ellison this morning, they expect to further increase this extraction next campaign by changes to be made in the sugar-end operation.

Final figures on regenerant consumption showed 20.44 pounds of 66 degrees Be' sulfuric acid and 11.81 pounds of anhydrous ammonia used per ton of beets. It is believed that these figures can be materially reduced next campaign.

The success of any new process is dependent upon its ability to improve the product and show a satisfactory economic balance. There is little doubt that the de-ionization process has proved its ability to show an improved product both in appearance and in chemical analysis. Ash determinations on the de-ionized sugar showed results of from .006 to .008 percent as compared to .025 to .035 percent for straight house produced sugar.

The economic balance was not as favorable as originally expected primarily due to the extremely high molasses prices at the present time. One of the major items on the debit side is some 1,400 tons of molasses that were not produced. It is gratifying, however, to note that there still was a substantial savings shown. To these tangible savings can be added such items as no shut-downs for boiling-out of evaporators and pans during the entire campaign, increased efficiencies of the sugar-end operation due to clean heating surfaces and the elimination of the pulling of tubes in the evaporators after campaign. While these are intangible savings on which no dollars and cents value can be placed, they do amount to thousands of dollars per year to a beet-plant operation.

# Harvesting Machinery

# Experience and Progress with International Sugar Beet Harvester

J. L. Hipple

During the season of 1947, International Harvester built and sold 600 sugar beet harvesters. In addition, the improvements which were embodied in the 1947 design were furnished to the owners of the three-hundred 1946 machines, so all International machines now in the hands of users are of the latest design.

One of the 1947 design machines was placed in operation at Calexico about the first of May and was in constant use, except for time lost in transporting from one location to another, until about the middle of November under many crop and soil conditions. This machine harvested approximately 5,000 tons of beets and averaged 6½ tons of beets per hour and 1 acre harvested for every 2½ hours of operation. Experience gained on this machine pointed to the desirability of some improvements which are included in the 1948 machines. In the heavy top growth and large beets found in the Imperial Valley some trouble was experienced in handling this heavy growth and large crowns with the receding finger top flinger unit. This flinger drum was mounted in a fixed position with relation to the topping disc. Excessive material passing through would sometimes clog and cause stoppages. The design of the mounting for the flinger drum was changed from a rigid construction to a floating arm which is held down to its normal working position under spring pressure but is allowed to move upward within certain limits to allow large amounts of material to pass through.

It was also found that in heavy growth some crowns would get by the flinger drum, so a cone was added to the topping disc shaft which keeps all material in the path of the flinger drum and prevents wrapping around the shaft.

A top conveyor unit was tested on this machine which takes the tops from the flinger and conveys them out beyond the tractor wheel where they are deposited on the ground. This unit consists of a potato link elevator driven from the tractor axle and the cleaning action of this unit leaves the tops in a loose windrow free from dirt and outside of the tractor wheel where they will lie undisturbed and in a condition to be windrowed by a side-delivery rake.

Several of these units were tested in different sections where they proved effective and will be listed as an attachment for the 1948 season.

Consideration is being given to means for windrowing several rows of tops in one windrow. There seems to be two lines of thought on the disposition of the beet top. Recently the idea of flailing or shredding the

tops from the beets with some type of beater previous to harvesting and leaving them on the ground to be plowed under to improve the fertility of the soil has been promoted in some sections. The original and so far most prevalent procedure is to recover them for feed by either pasturing them off in the fields or by storage for later feeding. We are not concerned with which method is followed but plan to devote our efforts to leaving the tops in the field, either scattered for field feeding or in condition to be raked off and stored.

Our harvester lends itself very well to this method since it is not necessary to go over the field behind or with the harvester with a tractor or field loader as the beets harvested are transported by the harvester. The harvester works equally as well in beets where the tops have been removed.

The International machine employs a revolving disc as a topping unit. Its use was old in the art of beet harvester design before we selected it as the most universally successful method of topping due to its ability to cut its way through heavy growth of tops as well as any obnoxious vegetation growing in the crop. It is not quite as easy to recover the tops from but its other advantages offset this. With the tendency toward closer spacing of beets in the row due to precision planting, and elimination of mechanical thinning as well as higher operating speeds, we recognize the necessity of a very active topping unit to efficiently top closely spaced beets of uneven height from the ground.

We have been testing a topper unit made from aluminum alloy having better bearings for the floating linkage which eliminates considerable dead weight without impairing the strength of the unit. This, of course, would greatly reduce the inertia of the unit and make its vertical movement much more active with less effort required of the finder unit. This will also improve its operation in beets grown in loose soils.

As we all know, the most difficult problem of mechanical beet harvesting is clod separation. For years many types and designs of beet harvesters were built, most of them successful under certain conditions. The use of spikes in some form or other has been tried for over 25 years and have been successful in certain conditions. Many means of agitation have been employed but were not successful in hard ground and mud. In adopting the hand-sorting means for our harvester we did not admit or accept defeat on this problem but accepted it as a compromise between the ideal and the practical for the purpose of providing the sugar beet industry with a harvester that would work in any and all types of soil and weather conditions instead of withholding it from the market until a successful mechanical clod separating or eliminating device was perfected. The idea of hand separation of foreign material from crops was not new and its application to beet harvesting had been tested by the late Professor Mervine at Fort Collins and Austin A. Armor at Davis, California.

We are still working on this problem of clod elimination. Many devices have been tried, some of them our own development and some developed by owners of our machines.

We have tested a spike wheel running directly behind the puller blades. Different types of puller units have been tested. A rotating lifting unit developed by T. H. Jenson of Lovell, Wyoming, has been investigated, also a spike wheel running over the sorting belt, designed by Mr. Walters of the Great Western Sugar Company at Windsor, Colorado. This device shows some merit. It is designed to run over the beets as they pass along the sorting belt and convey them up where they are stripped off the spikes into a chute delivering them into the cart, leaving the clods to go on over the belt onto the ground. We have tested a spike wheel mounted over the sorting belt where the beets were thrown onto the spikes from the harvester elevator. These spikes were sword shaped. This device was not successful. We will continue our efforts to devise some means to make complete mechanical beet harvesting successful under all conditions which is the aim of all those devoting their efforts to this problem.

The daily output of this machine, of course, varies with crop conditions and the efficiency of the operators. Daily averages of 60 to 80 tons was not uncommon. We had one outstanding report of a daily production which we did not accept without confirmation. One harvester working on the S. A. Camp ranch near Bakersfield in beets running 36 tons to the acre and in soil that did not require the use of the sorting belt took out 143 tons of beets in 11 hours. This, of course, we know is very unusual. The quota system applied in many places controls the daily output.

In closing, I wish to say that we know of no effort to mechanize a crop where greater cooperation has been given to all those who are attempting to design machinery to accomplish it than that given by the growers, the processors and agricultural colleges interested in the beet sugar industry.

# Sugar Beet Harvester Studies at the University of California

J. B. Powers[1]

Progress in the beet harvester development program at the University was discussed at a meeting of this Society at Denver, Colorado, in 1946. At that time the machine was reported to be functionally satisfactory under most conditions in the following operations: topping, top disposal, plowing, dirt separation, and root disposal. The root-pickup device was not considered satisfactory since the maximum recovery amounted to 85 percent, and this was deemed too low for successful field operation because of the expense of recovering the unharvested beets by hand methods. The complexity of the mechanism was admitted to be a formidable, though not necessarily an insurmountable barrier to operation by the average grower.

## Shop and Field Work—1946 and 1947

No changes were made in the fundamental operating principles of the machine during 1946 and 1947, and it now appears unlikely that such changes will be required in the development of a commercially acceptable machine. Mechanical improvement has now progressed to a point where most of the mechanism is field worthy in its present form, and beet loss has been reduced to a practical working level. Some of the mechanism is still susceptible to frequent failure; but changes made, especially during the past year, have opened new avenues for improvement.

Most of the 1946 harvest season was spent in the construction of a new digging and lifting unit and in the enlargement and remounting of the hopper. These changes required so much time that it was possible to spend only 12 days in actual field work; all in dry, sedimentary soil in the vicinity of Davis. Under these conditions, root recovery was approximately 90 percent as compared with 85 percent in 1945. However dump screenings of 10 percent nearly doubled the average of the preceding year.

Because of the limited field experience during 1946, it was deemed unwise to make major changes in the machine when work was resumed in 1947. Hence the spring of 1947 was spent in rebuilding only those parts of the mechanism which were obviously weak or faulty. Early field trials yielded no better results than those obtained in 1946. Faulty operation of a poorly designed hydraulic depth control system was finally isolated as one of the major sources of trouble. After rebuilding this, progress was rapid. Other faults which had been hidden by erratic performance then became apparent and most of them were corrected.

[1]Associate Agricultural Engineer, University of California.

On October 16, a test in dry, peat-loam soil at Clarksburg showed that root recovery had been raised to 93.7 percent and dirt pickup lowered to 6.8 percent. The fall rains began shortly thereafter and made further dry ground tests impossible. These results were definitely encouraging and if finally verified will indicate that recovery in such soil is on a practical working basis. However, further dry soil tests will be required before final judgment can be rendered.

During the remainder of the harvesting season, 294 tons of beets were harvested from three fields in the Clarksburg area under conditions ranging from moist to muddy. The results of these tests are summarized in table 1.

Table 1.
Results of Field Trials—1947

| Place | Acres harvested | Tons harvested | Factory screenings (percent) | Factory tare (percent) | Root recovery (percent) |
|---|---|---|---|---|---|
| Gus Olson, Clarksburg | 6.4 | 220 | 11.9 | 3.4 | 95 |
| Joe Holmes, Clarksburg | 1.3 | 28 | 5.7 | 4.0 | 90 |
| V. Hinsdale, Clarksburg | 1.9 | 46 | 5.6 | 2.1 | 92 |

Peak performance was obtained in moderately wet soil where the harvesting rate was approximately 7.5 tons per hour; dump screenings, 7.3 percent; top and dirt tare, 2.4 percent; and topping losses, 1.5 percent. All losses, excepting those due to low topping, were recovered by one man following the machine.

As soil moisture increased above the optimum level, root recovery improved, but dump screenings increased because of adhesion of dirt to the beet roots. Reconstruction of the beet elevator to provide greater agitation of the roots lowered screenings from 18.8 percent to 5.7 percent under very muddy conditions, but appreciable tap root damage from the rough handling of the beets was evident.

## Attainment of Fundamental Objectives

The fundamental objectives of this project were reviewed at Denver in 1946. Since development work at the University has now been terminated, appraisal of its success or failure must be based on an examination of the performance of the harvester in the light of these objectives. It is the opinion of those on the Davis staff who have worked with the machine that the following objectives have been attained:

1. All apparatus to be mounted on a standard wheel tractor for ready maneuverability.
2. No unusual skill to be required in operation of the machine.
3. All operations to be completed in one transit of machine through the field.
4. Machine to be capable of opening its own lands.

5. Topping to be satisfactory in beets ranging up to 9 inches in height and in tops of any size.

6. Topping loss under ordinary conditions not to exceed 1.5 percent and top tare not to exceed 3.5 percent.

7. Tops to be left clean and in acceptable condition for forage or harvesting.

8. Root losses after scavenging not to exceed 3 percent by weight.

The following objectives have been only partially fulfilled, or have been satisfied only under certain field conditions:

1. Harvest crew to consist of one machine operator and not more than one scavenger. (In its present state of mechanical development, the machine requires an additional man to watch for mechanical failures and other field contingencies.)

2. Beets to be delivered free of serious bruising or other injury. (Under dry field conditions, damage to roots is no greater than in manual harvest; under muddy conditions, the vigorous agitation required to clean the roots results in appreciable tap root damage.)

Wider harvesting experience will be necessary as a basis for judgment regarding the following requirements:

1. Operation to be possible in all ordinary soil types and field moisture conditions which permit operation of a wheel tractor.

2. Dump screenings not to exceed 5 percent of beet weight except in muddy conditions.

### Favorable Features of the Harvester

The harvester delivers a high quality of product with a minimum of loss. Beets are cleanly topped and topping losses do not exceed those for hand-topped beets. The roots are delivered free of injury which might result in tonnage loss to the farmer or in storage loss to the processor. Dirt inclusion is not sufficient to interfere with milling operations. Tops are left in good condition for forage or harvesting. Unharvested roots are left on the surface of the ground where they may be readily recovered by a scavenger. The overall harvesting losses are thus kept at a level which compares favorably with those incurred in manual harvest. Since, at present price levels, each 1 percent of root loss is equivalent to an increase in harvesting cost of 15 cents per ton, this item plays a greater part in determining the cost of harvest with present machines than is generally recognized.

Operation is possible under a wide variety of field conditions. Hard ground, mud, high beets, heavy top growth, and light top growth interfere less with the operation of this machine than with other machines now in commercial use. A high degree of maneuverability and the ability to open its own lands adapt the harvester to work in small fields. The beet hopper permits operation in fields far too wet for successful truck operation.

### Unfavorable Features of the Harvester

The most unfavorable feature of the machine is its mechanical complexity. This is due in part to lack of experience on the part of its designers and to the fact that all mechanism is mounted on a single tractor. Some of its operating principles, however, appear to demand mechanism which is undesirable from a construction and maintenance point of view.

The performance of the harvester is adversely affected by beets in multiple combinations, by a preponderance of small beets, and by beets of odd shape. In these respects, the machine is less tolerant than most of those in commercial use. These faults appear to be inherent, and their correction must occur through cultural improvements rather than through improvement in implement design.

Root recovery is reduced in hard, dry ground; but to what extent this might limit the usefulness of the machine has not been determined. Experience with previous models, however, justifies the assumption that this factor would not reduce the recovery to an impractical operating level.

### Conclusion

The University has completed its phase of the harvester development program. A machine has been produced which is capable of high quality performance under the conditions in which it has been tested. Harvesting losses are low, and performance is relatively independent of many field variables which seriously affect the commercial harvesters now in use.

The harvester is not, however, capable of practical field operation in its present state of mechanical development. It will require redesign along practical lines by an agency experienced in this work and extensive field trials to establish its ultimate merit.

# Beater Type Topper Use 1947–in Nampa Nyssa District of the Amalgamated Sugar Company

ROBT. VAN HORNE AND READ A. WILKINSON[1]

DURING THE 1947 harvest season the growers in the Nampa-Nyssa area harvested 28 percent of their crop with 293 beater toppers. While not all of these acres were 100 percent beater topped, beaters were used in some stage of the harvesting operation. This shows an increase in the percentage of total harvested acres beater topped, from 2.7 percent in 1946 to 28.7 percent in 1947, or approximately 360,000 tons beater topped during the past harvest season.

## Beater Harvest Costs

Costs of topping with beaters naturally varies with the type machine and acreage covered. Averaged individual growers figures indicate topping and loading costs with a two-shaft four-row beater topper and two-row lifter-loader to be 52 cents per ton not including depreciation nor trucking.

Costs of topping and loading with single shaft four-row type beaters used in conjunction with lifter-loaders indicate an average cost of nearly 65 cents per ton on the same basis, with the additional cost due to the necessity of additional trips with the beater to insure complete top removal.

Lifting and windrowing with single-row, standard-type harvesters, following beating, then loading with conventional loaders, was found to add nearly 15 cents per ton to either of the above operations. With no charge or credit assigned to crowners or clipping because this was usually done with the standard topping device already on the harvester, or a simple clipper was added to the equipment on some tractor already charged against the total operation.

## Beater Paddles

During the 1946 season, paddles and paddle attachments were a major problem. However, as a result of much experimentation satisfactory solid rubber paddles are now available which last considerably more than one season. Paddles can now be quickly replaced in case of failure due to a general swing on the part of manufacturers to "gang" attachments on rods instead of individual bolt attachment as was used in earlier models.

Two weights of paddles are standard, the heavier having a cross-section measuring 1½ inches by ¾ inches, the other being ⅞ inches

[1]Agricultural Superintendent Nampa, Caldwell District, and Agricultural Engineer, The Amalgamated Sugar Company, respectively.

square. Neither weight has enjoyed universal acceptance because of varying shaft speeds and field conditions. Practically all combinations have been tried. Observations indicate that alternate rows of each weight provide nearly ideal striking force for average field conditions. Lengths vary from 1 foot to 18 inches, depending on the make of machine.

Paddle quality research is continuing largely through the Gates Rubber Company in Denver, Colorado, who pioneered the field and developed the formula now used in the majority of our beater paddles.

### Beater Types

Single-shaft four-row beaters are available in two major designs, front mount or trailer type. Two-shaft machines are available in four-row, three-row, and two-row sizes and are all trailer types.

Power demand for satisfactory operation under all conditions has centered at approximately one-half horsepower per inch of shaft, with a definite trend toward auxiliary motors on all types of machines, primarily because of difficulties encountered in maintaining the proper shaft R.P.M. and ground speed relation where power-take-off drives were used.

No studies have been made to date of draw-bar horsepower demands, but where 100 percent auxiliary power is used the lighter types of ordinary farm tractors have no difficulty handling even the heavier types of beaters.

### Trash Comparisons

Shredding of tops beaten off presents somewhat of a problem where single-shaft type beaters are used in that though top removal is complete, some leaves remain nearly intact despite repeated trips with the beater. The two-shaft type machines seem to have extra shredding ability resulting in very little trash longer than 2½ to 3 inches, which is readily eliminated in the loader or lifter-loader.

Where topping and top salvage preceed beating, the problem of trash shredding is vastly simplified because of the great reduction in volume of bulk to be handled.

### Clipping or Scalping

Complete removal of the center bud requires slow ground speeds and uses approximately one-third of the total horsepower used. This so limited the daily capacity of beaters in general that soon various clipping devices appeared to supplement the standard topping devices. These clippers were the very essence of simplicity and often home-made. They featured a fixed depth of cut with a paring knife type blade attached to, and pulled by, an up-sloping boiler plate finder. Spring pressure or added weights were employed where an unusual number of low beets required special adjustments. These clippers allowed beaters to leave beets with "pineapple" like

tops still attached, which were clipped or scalped just prior to lifting, thereby allowing much faster beating as well as insuring a minimum of possible trouble from top growth in storage piles.

The various combinations of toppers and beaters were so numerous that it was decided to assemble all types of machines in one field where true comparative performance could be tested.

An acre and one-half of beets were selected for the trial. Due to the uncertainty of weather condition, at the advanced time of harvest this test was performed, an extremely sandy piece of ground was selected. Therefore, these results can not be interpreted as being comparable to what would be expected from the average beet field found within the Nampa-Nyssa districts. It can only be taken as comparative operation data for the units used in the experiment.

The purpose of this trial is two fold, first, to compare the different variations of beet-topping machines using the centrifugal beating principle, and second, to determine the relationship, by comparative test, of variable factors such as: 1. Angle of beater to row, 2. Ground speed, 3. Direction of rotation of beater, 4. Peripheral speed, and 5. Diameter of peripherary when incorporated within a combination knife and beater beet-topping machine.

Mechanical topping machines used were as follows: 1. A four-row two-shaft machine, 2. A single-row four vertical shaft machine, 3. A single row combination of a rotary disk knife and two-shaft beater with a small peripheral diameter parallel to row, 4. A single row stationary knife, single-shaft, small peripheral diameter beater unit, 5. A stationary knife, variable angle, variable rotation, large peripheral diameter beater unit, and 6. A stationary knife vertical brush unit upon which either wire or fibre brushes could be mounted.

Detailed information upon the above units is given on the enclosed data sheet.

The stationary knife units were equipped with leaf pickup and salvage units. However, a clipper unit was incorporated, which did not salvage the tops, for several tests to determine the effect of undisposed tops upon the efficiency of the beater toppers.

Different combinations of the above mentioned variables were tried and results tabulated. Each trial covered one row on which length was measured and acreage determined. The time required for the run was also taken and ground speed determined. Results of the run were measured by obtaining, through actual count, the percentage of total beets topped, the percentage of low beets topped, the percentage of doubles topped, and the percentage of beets knocked out.

From this data the enclosed curves were drawn and conclusions formulated.

Seventy different test runs were made from which the most efficient combinations or machines performing satisfactory work were selected and listed in table 1.

TABLE 1. DETAIL DATA OF MOST EFFICIENT TOPPERS

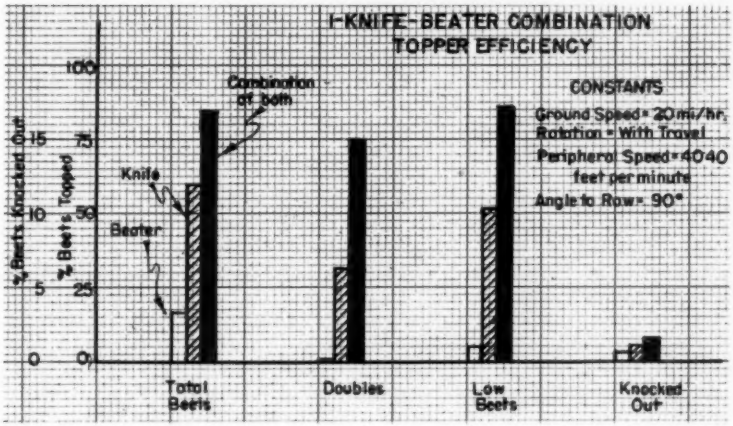
| Topper Combination | Topper No. | Power H.P. | Feed Rate | Tons Per Hr. | Tons Topped per Hour | Knife Cleaned | Knife A.D. Tension | Beater Cleaned | Beater Tension | Clearance Between Beater & Knife | Size | No. Blades | Blades Rotate | Diameter Beater | Weight of Beater | Beets Topped | Tons Topped | Topping Speed | Beet Retention | Retention No. Beets | Low Crowned | Beets Crowned | Beets Topped | Percent Topped | Percent Topped Crowned | Percent Topped Low Crowned | Percent Low Crowned |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 8 | 26 | .039 | 2.02 | 1 | .906 | | x | | x | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | 89° | C | | 1 | 1 | 2.99 | 99.5 | 100.0 | 97.5 | 2.98 |
| 2. | 1 | 24 | .063 | 2.38 | 1 | 1.68 | | | | | 15° | 3/4"x1/4" 7/8"x1/8" | 296 286 | 90 | 37 | 11 oz. 10 oz. | 600 | 5800 | 90° | C & CC | | 2 | 1 | 1.99 | 97.5 | 87.0 | 99.0 | 4.8 |
| 3. | 11 | 2.0 A | .017 | 2.02 | 1 | .845 | | x | | x | 9° | 7/8"x1/8" | 36 | 16 | 22 | 6 oz. | 1000 | 5760 | 90° | C | | 1 | 1 | 2.14 | 95.5 | 85.6 | 91.6 | 0 |
| 4. | 12 | 26 | .017 | 2.10 | 1 | .908 | | x | | x | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | 90° | C | | 1 | 1 | 2.32 | 99.0 | 88.03 | 88.5 | 45 |
| 5. | 18 | 26 | .017 | 2.03 | 1 | .902 | | x | | x | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | 89° | CC | | 1 | 1 | 2.30 | 88.3 | 70.0 | 80.3 | 9.6 |
| 6. | 6 | 26 | .016 | 2.15 | 1 | .87 | | x | | x | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | 90° | C | | 1 | 1 | 2.13 | 84 | 75.0 | 86.0 | 1.5 |
| | | | | | | | | | | | | MACHINE TYPE COMPARISON | | | | | | | | | | | | | | | | |
| 1. | Two Shafts | 52 | | | 1 | 1.58 | | | | | 15° | 3/4"x1/4" 7/8"x1/8" | 296 286 | 90 | 37 | 11 oz. 10 oz. | 600 | 5800 | 90° | C & CC | | 2 | 1 | 1.99 | 97.5 | 87.0 | 99.0 | 4.8 |
| 2. | 1 Shaft Small .60 knife | 2.0 A | | | 1 | .83 | | x | | x | 9° | 7/8"x1/8" | 36 | 16 | 22 | 6 oz. | 1000 | 5760 | 90° | C | | 1 | 1 | 2.14 | 95.5 | 85.6 | 91.6 | 0 |
| 3. | 1 Shaft .60 knife | 26 | | | 1 | .87 | | x | | x | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | 90° | C | | 1 | 1 | 2.13 | 84.0 | 75.0 | 86.0 | 1.5 |
| 4. | 1 Vert. Shaft | Con ver | | | 1 | .671 | | | | | 11° | 7/8"x1/8" | 20 | Vert. Shaft | 26 | 10 oz. | 750 | 5110 | Vert. Beater | To Beater | 4 | 1 | 3.24 | 92.8 | 60.0 | 89.5 | 4.8 |
| 5. | 1 Shaft Dragon | 26 | | | 1 | .550 | Dragon | Knife (Torque) Arm | | | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 650 | 5850 | 80° | CC | | 1 | 1 | 2.26 | 90.3 | 33.0 | 88.7 | .57 |
| 6. | 2 Shaft I.H.C. | IHC M | | | 1 | .33 | IHC Topper | | | 0 | 64° | 7/8"x1/8" | 20 | P-C P-CC | 13 | 8 oz. | 1100 | 3730 | 180° | C & CC | | 2 | 1 | 1.86 | 98.2 | 60.0 | 66.2 | 2.96 |
| 7. | 1 Shaft No Crown | 26 | | | 2 | .686 | Power Lift | Test Yield Poly. Knife by Hills no Crowns Same Knife Used | | | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | 90° | C | | 1 | 1 | 1.80 | 80.3 | 60.0 | 90.3 | .40 |
| 8. | 1 Shaft | 26 | | | 2 | .317 | | | | | 15° | 3/4"x3/8" | 48 | 31.25 | 31.25 | 14 oz. | 600 | 5350 | 90° | C | | 1 | 1 | 2.86 | 89.0 | 57.0 | 92.2 | 2.67 |
| 9. | Wide Groove .60 knife | 26 | | | 1 | .957 | | x | Wide | x | | | | | | | 950 | 2018 | Poor to Wide | CC Poor to Low | | 1 | 1 | 2.60 | 86.7 | 46.6 | 82.1 | 16.6 |
| 10. | 1 Shaft Spinning | 26 | | | 1 | .498 | | | | | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | | | x | 1 | 1 | 2.16 | 79.0 | 0 | 62.8 | 18.9 |
| 11. | 1 Shaft Spinning .60 knife | 26 | | | 1 | .616 | | x | | x | 15° | 7/8"x1/8" | 51 | 31.25 | 31.25 | 10 oz. | 450 | 4060 | | | x | 1 | 1 | 1.99 | 99.0 | 60 | 88.5 | 12.6 |

The selection was made as follows: Of the 70 runs, those were chosen which topped from 80 to 100 percent of all beets. From this 38, those were retained which topped from 80 to 100 percent of the low beets. Of these 23, those were selected which topped from 70 to 100 of the doubles. In each selection the runs were listed according to the percentage topped, number one being the highest percentage and the last one being the lowest percentage topped, the rank of each being noted. These remaining six were ranked according to the percentage of beets knocked out by them and their average ranking made. A listing according to rank is made in table 1 with pertinent detailed data.

In table 1 is also found a list of the different machines, or combinations used, so that a comparison of the efficiency between them may be made.

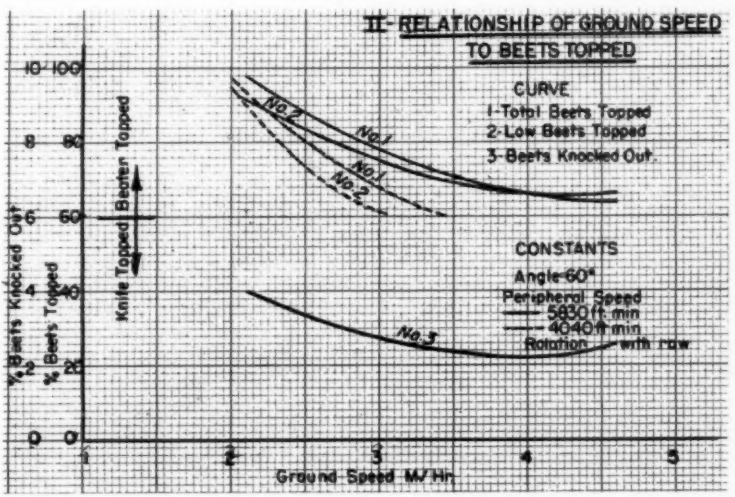
## Explanation and Interpretation of Curves and Charts

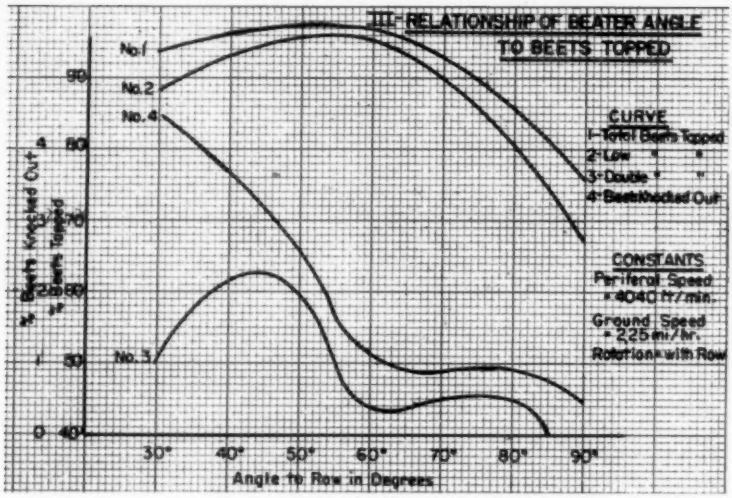
Chart No. I.—This chart is given to provide a balance in the interpretation of the following curves which give the results of tests with the combination system of topping. It will be noted here that neither the beater nor the knife alone top satisfactorily but the combination of both top an acceptable percentage. It should be noted also that the knife unit alone tops about 60 percent of the beets satisfactorily, 30 percent of the doubles, and 52 percent of the low beets.




Curve No. II —Shown here is the reduced efficiency of the combination through increased ground speed. It will be noted that the curves level out at about 62 percent which shows that the beater becomes ineffective at that point and the remaining beets topped are those topped by the knife unit.

The dotted curve shows the effect of reduced peripheral speed upon efficiency of machine becoming inaffective at lower ground speeds.

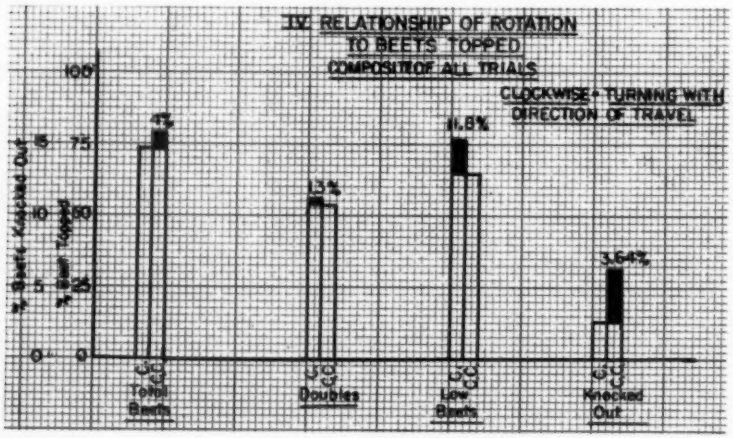


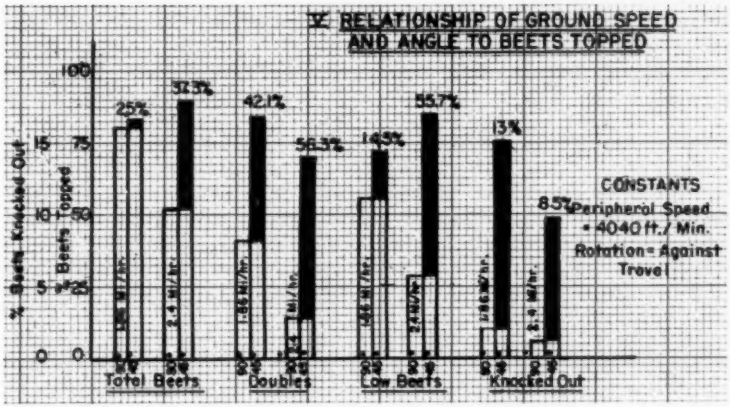



Curve No. III.—Efficiency of a beater increases as it is turned at an angle with the row up to about 52 degrees. More doubles are topped at 45 degrees but the rapid increase of beets knocked out from 60 degrees down to 30 degrees would cause hesitancy as to the selection of such an angle.

It will be noted that the only variable having any appreciable effect upon doubles topped is that of angle variation.

Chart No. IV.—The dark portion of the bars give the percentage of decrease in beets topped through the change in direction of rotation of

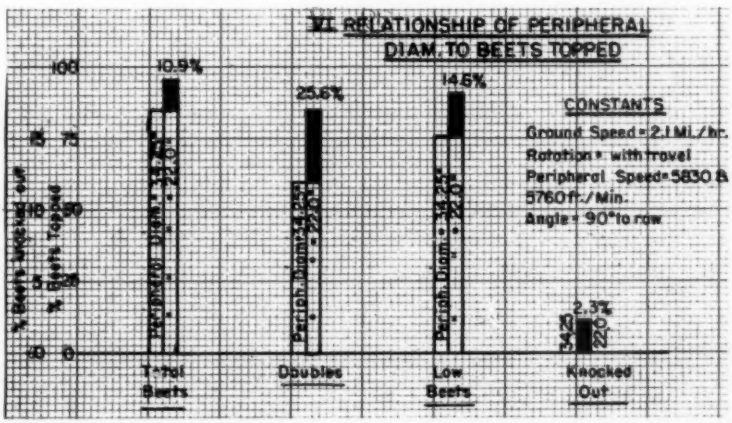





the beater. A slight increase in total beets topped is noted but this is offset by the larger percentage knocked over. Very little effect upon the doubles topped results from change in rotation.

Chart No. V.—The purpose of this chart is to show the increased efficiency of an angle beater at higher ground speeds. Very little difference in percentage of doubles topped is evident, however, a marked decrease in beets knocked out at higher speeds with angle beaters is manifest.

Chart No. VI.—An interesting contrast between beaters with larger and smaller peripheral diameters but the same peripheral speed may be noted on this chart. The absence of beets knocked out by smaller diameter beaters brings to the fore a point for consideration.



## Conclusions

The following are general conclusions which may or may not be applicable in the majority of cases but are based upon data and observations of the preceding series of test runs as were here-in described.

1. A single-shaft beater topper is more efficient, covers more acreage in less time with less operating costs when in combination with a knife.

2. When using a beater topper behind a knife a smaller diameter peripherary with high peripheral speed is just as efficient as the larger diameters with slower speeds and it uses less power, reduces over-all weight of machine and permits, therefore, a greater ground speed.

3. The efficiency of a single-shaft combination unit is increased if the knife is set to cut a sloping cut through the crown of the beet. The direction of dip depending upon the rotation of the beater, towards the approaching side if the beater is rotating with the direction of travel and towards the far side of the beet if the direction of rotation is against travel.

4. A beater becomes more efficient when placed at an angle of from 60 degrees to 80 degrees to the row, as it tops more low beets and doubles at this angle and clears more trash from the row.

5. The most difficult portion of the foliage of a beet to beat off is that connected to the top of the crown. Side stringers are removed with much less power. Therefore, removal of the top portion of the beet foliage can best be accomplished with less power by a knife.

6. A beater topper placed at an angle to the row other than 90 degrees requires more power, a larger number of paddles, beet is hit more times at same ground speeds by paddles than when at 90 degrees to row.

7. Counter-clockwise rotation of beater provides a small increase in efficiency, however, such is offset by the increase in the percentage of beets knocked out.

8. An increase in ground speed must be accompanied with an increase in peripheral speed to provide comparable efficiencies. However, higher ground speeds are permissable with the same peripheral speeds, if the beater topper is placed at an angle of 45 degrees to 60 degrees to the row. More power is required in the latter case.

9. Results indicate that when a beater is at 90 degrees to row peripheral speed of 4.040 feet per minute will continue to top beets up to 2¼ miles per hour. A peripheral speed of 5,830 will top up to 3 miles per hour. When the beater is at an angle of 60 degrees to the row a peripheral speed of 4,040 feet per minute will top up to 2¾ miles per hour, and a speed of 5,830 will top up to 4 miles per hour. Efficiency decreasing to zero as the higher mileage is reached.

10. Increased peripheral speed at low ground speed 90 degrees to row appears to affect only a small change in efficiency, however, this increase greatly increases efficiency at higher ground speeds. If beater is at an angle to row, the reverse appears to be true.

11. Only factor effecting percentage of doubles topped is that of angle of beater to row.

12. Beets knocked out increases with slower ground speeds, a decrease in angle of beater to row from 90 degrees to zero degrees, higher peripheral speeds, greater peripheral diameters, rotation against direction of travel, and use of heavier paddles.

13. Efficiency of beater is increased when tops are salvaged and windrowed away from area covered by beater.

14. The use of wire brushes vertical to the row are not satisfactory due to the fact they knock too high a percentage of beets out and do not eliminate trash. Fibre brushes have little or no topping power but continue to knock out a high percentage of beets.

We are not convinced that the large beaters now in use are the final and perfect way to top beets. We also realize that beater topping does not have universal appeal in spite of the low harvest costs possible. However, we do believe in high topping as such, and feel that adaptation of some mutation or variation of beating into the future mechanical beet harvestors will better insure "streamer" free, trash free, delivered beets which are ideal for storage. Introduction of the additional crown borne impurities into the mill processing has been somewhat of a problem, but the ease of harvesting with beaters as well as the financial savings to growers has over shadowed the processing problem.

# Experiences During 1947 with the Scott-Urschel Beet Harvester

P. A. Reeve[1]

During the fall of 1946, 130 mechanical sugar beet harvesters operated in the area represented by the Farmers & Manufacturers Beet Sugar Association. Table 1 is a breakdown of these harvesters.

**Table 1.**

| Harvester make | Number | Total acres | Acres per machine |
|---|---|---|---|
| Scott-Urschel | 120 | 8,077.9 | 67.3 |
| International | 6 | 220.5 | 36.75 |
| John Deere | 3 | 85.0 | 28.3 |
| Marbeet, Jr. | 1 | 72.0 | 72.0 |

Table 2 gives a breakdown of beet harvester operations in this same area for 1947.

**Table 2.**

| Harvester make | Number | Total acres | Acres per machine |
|---|---|---|---|
| Scott-Urschel | 256 | 14,882.6 | 58.13 |
| International | 36 | 1,722.7 | 47.85 |
| Others | 6 | 132.7 | 22.1 |

Table 3 gives a breakdown of Scott-Urschel harvester operations in 1947 by year model.

**Table 3.**

| Model | Year | Number | Total acres | Average |
|---|---|---|---|---|
| Regular chain | 1945 | 10 | 430.8 | 43.08 |
| Regular chain | 1946 | 102 | 5,495.0 | 53.9 |
| Regular chain | 1947 | 124 | 7,776.8 | 62.7 |
| Regular V-belt | 1947 | 10 | 744.1 | 74.41 |
| Stub bar—V-belt | 1947 | 5 | 435.9 | 87.2 |
| Not operated | ---- | 5 | ---- | ---- |

Data from four factory areas give the following information.

**Table 4.**

| | Number of machines | Total acres | Average |
|---|---|---|---|
| Scott-Urschels loading direct into trucks or wagons | 59 | 3,557.1 | 60.0 |
| Scott-Urschels equipped with side-dump carts | 25 | 1,849.1 | 74.0 |

Table 5 gives the cost of repair parts for 193 Scott-Urschel machines for the 1947 season. These figures do not include welding costs or costs of

[1]Agricultural Supervisor, Farmers & Manufacturers Beet Sugar Association, Saginaw, Michigan.

parts bought by the farmers from outside sources, such as bolts, chain, etc.; also these figures do not take into consideration the inventory of parts which the farmers might have on hand.

**Table 5.**

| Name of harvester | Number of machines | Number of acres | Parts cost | Acres per machine | Parts cost per acre |
|---|---|---|---|---|---|
| Scott-Urschel | 193 | 11,135.8 | $15,533.93 | 57.7 | $1.39 |

The beet sugar companies of the Eastern area are ordering all Stub-Bar Scott-Urschel Sugar Beet Combines for 1948.

The advantages of the Stub-Bar over the regular Scott-Urschel are:

1. Simplified lighter machine with fewer moving parts.
2. Lower maintenance cost.
3. Lower operational cost.

The following changes are being made on the 1948 regular Scott-Urschel Harvester:

1. Elimination of the wood sidings on the inside of the beet elevator.
2. Increased size and capacity in the lower beet conveyor to eliminate plugging with beets and mud.
3. Bolt tighteners for wire leaf-top conveyor belt.
4. Three rods on leaf pick-up points to give better leaf gathering.
5. Improved and strengthened tractor hitch and bar.
6. Clod guard for leaf pick-up chain or belt.
7. Slip clutch on drive shaft for topping discs.
8. Improved kicker and hopper arrangement in bottom of beet elevator.
9. Elimination of elevator chain slide shoe.
10. Elimination of reverse flanged idler wheel on top of beet elevator.

The following accessories will be available for the regular Scott-Urschel Harvester:

1. Beet Windrower—$125.00.
2. Top Windrower—$125.00.
3. Coulters and brackets for mounting same in front of leaf pick-up points for use in weedy fields and fields with heavy top growth.

Table 6 gives information furnished by the American Crystal Sugar Company.

**Table 6.—American Crystal Sugar Company, Chaska Factory, Scott-Urschel sugar beet combine performance in 1947.**

| Acres harvested | Total tons | Labor cost | Parts cost | Welding cost | Gas and oil | Total operating cost | Cost per acre | Cost per ton | Labor per hour | Tons per acre |
|---|---|---|---|---|---|---|---|---|---|---|
| 49 | 302 | $201.60 | $34.00 | $1.00 | $34.16 | $270.76 | $5.53 | $.90 | $.80 | 6.37 |
| 106 | 999 | 360.00 | 68.00 | 5.00 | 71.50 | 504.50 | 4.76 | .51 | .80 | 9.42 |
| 57 | 536 | 330.40 | 34.00 | 5.00 | 34.00 | 403.40 | 7.07 | .75 | .80 | 9.40 |
| 91 | 878 | 336.00 | 68.00 | 2.00 | 41.20 | 447.20 | 4.90 | .51 | .80 | 9.60 |
| [1]8865 | 674 | 274.55 | 172.87 | --- | 75.24 | 522.07 | 5.90 | -- | -- | 7.6 |
| [2]7833 | 677.8 | ---- | 75.37 | 3.25 | 51.22 | 429.59 | 5.63 | -- | -- | -- |

[1]Mason City Factory.
[2]Average.

Table 7 gives information furnished by the Great Western Sugar Company for the Scott-Urschel Combines which operated in their territory.

**Table 7.**

| No. of machines | Total acres harvested | Total tons | Custom acres harvested | Custom tons | Total days harvesting | Acres harvested per day |
|---|---|---|---|---|---|---|
| 41 | 2,117 | 39,606 | 205 | 3,454 | 1,020 | 2.13[1] |

[1]Average.

Tables 8 and 9 give information furnished by the Utah-Idaho Sugar Company for the Scott-Urschel Combines which operated in their Belle Fourche territory.

**Table 8.**

| Number of Machines | Tons harvested | | Acres hervested | |
|---|---|---|---|---|
| | Total | Average per machine | Total | Average per machine |
| 17 | 368.97 | 21.7 | 3,474.54 | 204.38 |

**Table 9.**

| Tractor used | Total acres harvested | Total tons harvested | Total hours due to delay machine breakdown | Total days of operation | Total cost of operation | Acres harvested per day | Cost per acre | Tons harvested per day | Cost per ton |
|---|---|---|---|---|---|---|---|---|---|
| Case CC | 27.70 | 316 | 16 | 14 | 219.20 | 2.31 | 7.90 | 26.33 | .69 |
| D-2 | 54.39 | 530 | 16 | 22 | 434.00 | 2.47 | 7.98 | 24.09 | .82 |
| Case S-C | 36.37 | 443.60 | 5 | 16 | 299.10 | 2.273 | 8.223 | 27.725 | .6742 |
| Oliver 70 | 34.00 | 461.84 | 15 | 22 | 366.90 | 1.545 | 10.79 | 20.992 | .794 |

# Observations on Mechanical Beet Harvesting in the Great Western Sugar Company Area in 1947

P. H. McMaster[1]

Farmers in the territory served by the Great Western Sugar Company saved approximately three quarters of a million dollars in 1947 by harvesting 644,196 tons of beets with machines rather than by hand. This represents an average saving of almost $650 for each of the 1,085 growers who harvested their crop mechanically.

A total of 45,748 acres were harvested with machines by the 1,085 growers, or approximately 20 percent of the total acreage. The percentage varied greatly between factory districts and states.

The Colorado district harvested an average of 15 percent of the acreage with machines; with the Brush and Fort Morgan factory districts leading with an average of 26 percent, followed closely by the Fort Lupton district with 21 percent.

In the Nebraska district, machines harvested 32 percent of the crop. Unfavorable weather and soil conditions materially reduced the actual from the expected. This is an increase of only 7 percent over 1946, which is not quite a fair comparison, however, because of the larger total acreage harvested in 1947. The comparative figures on acres harvested in 1946 and 1947 are:

| | 1947 | 1946 |
|---|---|---|
| Total acres | 46,418 | 38,516 |
| Harvested by mach'ne | 14,775 | 8,758 |

Wheatland harvested 24 percent of the crop mechanically as compared to 16 percent in 1946.

The percentage of total acreage harvested by machines in the Billings and Lovell districts was 21 percent and 40 percent, respectively, Lovell having the highest percentage of all Great Western factory districts.

The highest performance was at Billings with an average of 57 acres per machine. Sterling and Lovell follow closely with 49 and 48 acres respectively. Details for each factory are shown in table 1.

As indicated in table 1, the average performance in Nebraska in 1947 did not equal that of 1946 because of unfavorable weather and soil conditions. Dry and cloddy soil conditions early in the season prevented

[1]District Manager, Nebraska-Wyoming area, The Great Western Sugar Company, Scottsbluff, Nebraska.

fullest use of machines. We have been fighting snow, mud and frost since November 5, and obviously the fullest and most efficient use could not be made of machines under such conditions. We only completed the harvest last Saturday (January 10, 1948). Some tonnage is still left in the ground.

**Table 1.—Acres and tons harvested—all machines.**

| | Number of machines | Acres harvested | Tons harvested | Per machine Acres | Per machine Tons |
|---|---|---|---|---|---|
| Billings | 101 | 5,786 | 79,044 | 57 | 782 |
| Lovell | 52 | 2,504 | 38,853 | 48 | 747 |
| | 153 | 8,290 | 117,897 | 54 | 770 |
| Eaton | 54 | 2,451 | 43,308 | 45 | 802 |
| Greeley | 28 | 977 | 16,101 | 35 | 575 |
| Windsor | 38 | 1,600 | 28,345 | 42 | 746 |
| Fort Collins | 18 | 668 | 11,063 | 37 | 615 |
| Loveland | 32 | 1,266 | 20,511 | 40 | 641 |
| Longmont | 27 | 1,010 | 16,402 | 37 | 607 |
| Brighton | 25 | 586 | 8,807 | 23 | 352 |
| Fort Lupton | 57 | 2,511 | 44,733 | 44 | 785 |
| Ovid | 53 | 2,049 | 23,032 | 39 | 435 |
| Sterling | 29 | 1,415 | 17,113 | 49 | 590 |
| Brush | 75 | 3,148 | 34,831 | 42 | 460 |
| Fort Morgan | 92 | 4,139 | 63,305 | 45 | 688 |
| | 528 | 21,820 | 327,551 | 41 | 620 |
| Scottsbluff | 75 | 3,061 | 41,572 | 41 | 554 |
| Gering | 104 | 3,726 | 51,122 | 36 | 491 |
| Bayard | 63 | 2,473 | 26,721 | 39 | 424 |
| Minatare | 43 | 1,662 | 18,824 | 39 | 438 |
| Mitchell | 50 | 1,874 | 22,702 | 38 | 454 |
| Lyman | 50 | 1,979 | 25,963 | 40 | 519 |
| | 385 | 14,775 | 186,904 | 38 | 485 |
| Wheatland | 19 | 863 | 11,844 | 45 | 623 |
| Grand totals and averages | 1,085 | 45,748 | 644,196 | 42 | 594 |

There were 1,085 machines operated in Great Western territory in 1947. This is an increase of 560 machines over 1946. The distribution between states or districts is shown in table 2.

**Table 2.—Distribution of harvesters between states or districts.**

| | 1946 | | 1947 | |
|---|---|---|---|---|
| | Number of machines | Acres harvested | Number of machines | Acres harvested |
| Colorado | 240 | 6,257 | 528 | 21,820 |
| Nebraska | 205 | 8,758 | 385 | 14,775 |
| Lovell | 22 | 1,060 | 52 | 2,504 |
| Billings | 48 | 1,294 | 101 | 5,786 |
| Wheatland | 10 | 555 | 19 | 863 |
| | 525 | 17,924 | 1,085 | 45,748 |

**The above shows much better performance in 1947 than in 1946.**
**The number of machines increased 107 percent, but the acreage harvested increased 156 percent.**

The International harvester, which was used extensively for the first time in 1947, performed very satisfactorily under almost every condition that a machine could reasonably be expected to operate, and as a result of this performance the International combine harvester is generally acclaimed by owners and others as a satisfactory machine. Users are critical only of the lack of equipment for conserving the beet tops.

The combined harvester and loader is a feature liked by most farmers, as well as the picking table that permits sorting of clods and rocks when conditions make such operations necessary.

These machines performed very satisfactorily under some very unfavorable conditions—snow, mud and frost. Traction for the tractor was the limiting factor in the snow and mud. The serrated disk knife did a better job of topping and held its edge longer than the solid disk.

This machine has gained the favor of farmers and the only thing that might deter growers from buying as many as can be manufactured in 1948 would be the lack of a beet-top conserving attachment. I believe the machine will ultimately need to be equipped with a more complete top-handling unit than the short cross elevator provided on a few machines in 1947.

The John Deere harvester predominated in the number of machines but the International surpassed in the acreage worked per machine. Performance varied widely, as in previous years, according to conditions. Early in the season dry, cloddy soil conditions almost stopped the use of a large number of John Deere machines, but fortunately timely rains remedied this condition. Had the rains not occurred we would have been faced with a real problem. It would have been impracticable to have continued using the harvesters, and hand labor was not available to do the work expected of the machines.

The John Deere harvester has two features to recommend it, namely, the quality of the topping and the method of conserving beet tops. Farmers generally, and others, feel this harvester has two faults:

1. Too light construction, consequently excessive breakage that makes for delays and high maintenance costs.

2. Lack of facilities for eliminating clods and rocks.

It is hoped the manufacturer can overcome these objectionable features because the John Deere harvester has many features to commend its performance.

The Scott Urschel harvester was used in a limited way in Colorado this past year. Unquestionably this machine has a greater daily capacity than any other machine successfully used in Great Western territory. Many growers reported harvesting 3 acres per day and a few, under favorable conditions, were able to harvest 4½ to 5 acres of 18- to 20-ton beets, or 70 to 100 tons per day. High daily performances reported were 103, 96 and 80 tons per day.

This machine, also, lacks equipment for conserving the beet tops, which is a requisite in our area for any satisfactory harvester. Nevertheless this machine has been widely accepted after this year's performance and some large-acreage growers who used these harvesters in 1947 are ordering the second machine for 1948. They expect to provide a top-handling unit of their own design if the manufacturer does not provide equipment at the factory.

While many farmers object to the extra expense incurred, or the extra trucks required for loading directly into trucks and to the truck packing the ground, especially in wet weather; others object to windrowing the beets and then loading out of the windrow, with the complication of clods and rocks. They are general in their praise of the pull-type harvester because the tractor can be readily freed for other work during beet harvest.

Some growers have suggested that a trailer be provided for accumulating topped beets. This would not only eliminate the objection stated above, but would probably simplify the problem of providing a means of conserving the beet tops.

**Table 3.—Recapitulation of mechanical harvester operations in the Great Western Sugar Company area in 1947.**

| Make of harvester | Number of machines | Acres harvested | Tons harvested | Per machine | |
|---|---|---|---|---|---|
| | | | | Acres | Tons |
| John Deere | 675 | 25,533 | 345,579 | 38 | 512 |
| International | 305 | 16,007 | 228,666 | 52 | 750 |
| Scott-Urschel | 49 | 2,443 | 45,640 | 50 | 932 |
| Kiest | 53 | 1,724 | 23,636 | 33 | 446 |
| Marbeet | 2 | 35 | 635 | 18 | 318 |
| Trinkle | 1 | 6 | 40 | 6 | 40 |
| Totals | 1,085 | 45,748 | 644,196 | 42 | 594 |

Some people were fearful of the performance of this machine after the tops had been badly frozen, but the performance this past year has erased such fears.

One experimental Marbeet, Midget, was used to a very limited extent on our Windsor farm. It was reported to have done a very satisfactory job of topping and lifting, but it too had the objectionable lack of beet-top conserving equipment.

This machine demonstrated well in the Billings district, but its performance was very disappointing in the demonstrations held at Wheatland and Mitchell. The crowns of the beets had been frozen and the spikes tended to break off the crowns instead of lifting the beets.

While I did not see this machine in operation, I am told it is not entirely satisfactory.

Twenty five growers purchased 1947 model Kiest harvesters and ten farmers tried to use the machines they bought in 1946, which were rebuilt and supposedly would perform satisfactorily in 1947. Not more than a third of the growers owning Kiest harvesters were able to complete their harvest with this machine. These harvesters have been a dismal failure the past 2 years and until the manufacturer can demonstate efficient and economical performance, I think growers will be hesitant to purchase these machines.

My opening statement that growers in Great Western territory saved approximately three quarters of a million dollars by harvesting with machines instead of by hand, is predicated upon a report of the University of Nebraska, Department of Agricultural Economics, in which they show the comparative per ton costs of harvesting and loading beets by several methods.

For the past 3 years the Department of Agricultural Economics, under the direction of Professor Frank Miller, has made cost studies in cooperation with farmers in the various beet-growing areas of Nebraska. The delayed harvest has prevented some farmers sending in final figures, but based upon the reports received earlier, Professor Miller has issued a preliminary report, tables from which follow:

**Table 1.—Representative costs of using a mechanical beet harvester and a mechanical beet loader in Nebraska, 1947, as determined from survey made by Rural Economics Department, University of Nebraska.**

| | Harvester | Loader | Combined harvester and loader |
|---|---|---|---|
| Number of records | 22 | 16 | 7 |
| Average cost of machine | $998 | $732 | $2,664 |
| Average years of life (estimated by the users) | 5 | 9 | 6 |
| Average use in 1947 | | | |
| Acres | 64 | 65 | 71 |
| Hours | 174 | 42 | 179 |
| Tons | 787 | 800 | 873 |
| Average cost in 1947 | | | |
| Depreciation | $232 | $92 | $444 |
| Repairs, repairing and lubricants | 138 | 18 | 63 |
| Shelter, interest, insurance, taxes | 39 | 26 | 98 |
| Total | $409 | $136 | $605 |
| Unit costs in 1947 | | | |
| Per acre | $9.55 | $2.29 | $8.73 |
| Per hour | 3.51 | 3.55 | 3.46 |
| Per ton | .78 | .19 | .71 |

**Table 2.—Cost of harvesting and loading sugar beets yielding 12.3 tons per acre with mechanical equipment in 1947 as determined from a survey made by the Rural Economics Department, University of Nebraska.**

| | Harvester | Loader | Combined harvester and loader |
|---|---|---|---|
| Number of records | 16 | 16 | 7 |
| Average use of machine in 1947 | | | |
| Acres | 64 | 65 | 71 |
| Hours | 174 | 42 | 179 |
| Tons | 717 | 738 | 941 |
| Acres per machine hour | .37 | 1.55 | .40 |
| Average cost per acre | | | |
| Use of machine | $ 9.59 | $2.29 | $ 8.71 |
| Tractor power | 2.78 | .55 | 2.82 |
| Labor (one man to operate machine) | 4.61 | .71 | 3.20 |
| Gleaning fields | 1.86 | -- | 1.20 |
| Total | $18.84 | $3.55 | $15.93 |
| Average cost per ton | $ 1.67 | $ .31 | $ 1.20 |
| Average cost per hour | | | |
| Use of machine | $3.52 | $3.53 | $ 3.46 |
| Tractor power | 1.02 | .84 | 1.12 |
| Labor (one man to operate machine) | 1.20 | .93 | 1.06 |
| Labor to glean fields | .84 | -- | 1.00 |

Table 3. Cost of harvesting and loading sugar beets yielding an average of 12.3 tons per acre by various methods in 1947 as determined from a survey made by Rural Economic Department, University of Nebraska.

| Item | Combined harvester and loader | Harvesting with machine and loading with machine | Harvesting with machine and loading by hand | Harvesting by hand and loading with machine | Harvesting and loading by hand |
|---|---|---|---|---|---|
| | | | Cost per acre | | |
| Use of harvester | $8.73 | $9.55 | $9.55 | --- | --- |
| Tractor power | 2.82 | 2.77 | 2.77 | --- | --- |
| Wages of operator | 3.21 | 4.59 | 4.59 | --- | --- |
| Use of loader | --- | 2.29 | --- | $2.29 | --- |
| Tractor power | --- | .55 | --- | .55 | --- |
| Wages of operator | --- | .71 | --- | .71 | --- |
| Gleaning fields | 1.20 | 1.86 | 1.86 | --- | --- |
| Use of puller (2-row) | --- | --- | --- | .45 | .45 |
| Tractor power | --- | --- | --- | 1.00 | 1.00 |
| Wages of operator | --- | --- | --- | 1.34 | 1.34 |
| Wages for hand topping | --- | --- | --- | 19.68 | 19.68 |
| Wages for hand loading | --- | --- | 9.22 | --- | 9.22 |
| Total | $15.96 | $22.32 | $27.99 | $26.02 | $31.69 |
| | | | Cost per ton | | |
| | $1.30 | $1.81 | $2.28 | $2.12 | $2.58 |

Wages for machine operators and gleaners were charged at the rate paid by the farmer.
Hand topping was charged at $1.50 per ton.
Hand loading was charged at 75 cents a ton.

It was again demonstrated that harvesters will not work as satisfactorily under some conditions as hand labor. On the other hand, harvesters will operate satisfactorily under conditions where hand labor refuses or cannot work.

It has also been demonstrated again that successful operation is largely dependent upon the operator. There may be a slight difference in the construction of machines of the same make and we know there is wide variation in field conditions that will directly affect the performance of the machine, but generally the success or failure of the machine can be attributed to the operator.

I repeat here a statement made at Salt Lake City a year ago: "While some improvements are needed on the harvesters in general use, the greater need is for more harvesters of the improved designs."

# A Review of the 1947 Mechanical Harvest in California

AUSTIN ARMER[1]

IN THE YEARS following 1943, the mechanical harvest of sugar beets in California has followed a growth curve of such proportions as to point toward almost total mechanization in 1949. The factors influencing this rapid acceptance of mechanical harvest have been many and have changed with the passing of the years.

The original impetus to the adoption of harvesting machinery was imparted by the war-caused labor shortage, but other factors served to accelerate the acceptance of mechanical harvest during the post-war years. These are the factors which will receive special attention in this discussion.

The general scheme of mechanical harvest in California has gone through three phases. These are:

1. Renting of sugar beet harvesters by growers from processors.
2. Acquiring of sugar beet harvesters by growers and commercial operators.
3. Increased utilization of the services of commercial operators and a decrease in the number of harvesters rented or owned by growers.

The year 1947 definitely fell into the third phase. Commercial operators performed a large fraction of the total harvest, and their acceptance by growers has grown in proportion to their dependability and quality of work. At least five commercial operators so planned their 1947 program as to start in the earliest harvest district (Imperial Valley) and terminate in the latest northern California districts. Thus, they were able to harvest well over a thousand acres with each two-row Marbeet harvester in this service.

*Extent of Mechanical Harvest in California During* 1947.—It is unfortunate that the relatively accurate performance records maintained by processors during 1945 and 1946 were not continued during 1947. It would appear that since 1947 marked the passing of mechanical harvest from the first to the second phase, the details of this harvest were left up to the individual grower and commercial operator with far less processor participation. Due to this lack of accurate record keeping by processors in 1947, it is not possible to present an accurate measure of the percentage of California's sugar beet acreage harvested mechanically in 1947.

The data derived from the records of processors and commercial operators, however, form a basis for the 1947 estimate, and it appears

[1]Agricultural Engineer, Spreckles Sugar Company, California.

that very close to 69 percent of California's sugar beet acreage was harvested mechanically in 1947. (This compares to 55.5 percent harvested mechanically in 1946.) This 69 percent figure has a probable accuracy of plus or minus 2 percent.

*Types of Harvesters Used in California During* 1947.—The early acceptance of the Marbeet harvester in California has been maintained with the result that this harvester accounted for far the largest portion of the acreage harvested. Approximate figures for various harvester makes are herewith tabulated:

| | |
|---|---|
| Marbeet | 66 percent |
| McCormick-Deering | 2 percent |
| Other | 1 percent |

The Marbeet harvesters were divided into single- and double-row types—the latter having been responsible for most of the mechanically harvested acreage in California. These harvesters benefited as a result of several minor improvements conceived principally by the sugar beet processors and executed by the Blackwelder Manufacturing Company. There was a moderate acceptance by growers of the top windrowing attachment, the defoliator and rear mounted coulters. The Agricultural Engineering Department of the Spreckels Sugar Company developed these devices which were made available by the Blackwelder Manufacturing Company. There can be little doubt that these devices contributed to the acceptance of mechanical harvesters and served to accelerate their adoption in 1947.

The International Model HM-1 sugar beet harvester likewise benefited from minor improvements, and its utilization in 1947 was approximately double that of 1946.

*Harvester Performance Improvement Necessary to Induce Complete Mechanization.*—With labor becoming constantly more available, the extent to which mechanical harvest becomes complete depends to a large extent upon the mechanical perfection of the machines. Whereas those growers availing themselves of commercial operators do not concern themselves greatly with the operating inconveniences of existing harvesters, they are directly concerned with the performance of the machines in regard to quality of topping and field losses. These two items, therefore, remain the subject calling for the most attention on the part of harvester manufacturers in the immediate future. Needless to say, these manufacturers are well aware of these requirements and are exerting much effort toward improving their machines. The processors likewise are mindful of the contribution they can make and will undoubtedly contribute to the near future improvement of harvesting equipment.

*Impairment of Harvester Efficiency by Adverse Field Conditions.*—The prediction that 1949 will see almost complete mechanization in California is clouded by the fact that California's cultural practices frequently tend to produce sugar beet fields in which mechanical harvest

is very difficult. Foremost among the difficult field conditions encountered is the problem of weeds at harvest time.

The presence of weeds in sugar beet fields is certainly not intended by California growers; neither is it permitted when circumstances make it economically possible to minimize weed growth. It is the economical limit of weed control which will continue to act as an inhibitor to complete harvest mechanization and which may conceivably contribute to the continued use of hand labor in a few fields.

To those concerned with the eventual complete mechanization of the California sugar beet harvest, it therefore becomes their duty to concentrate on the redesign of harvesting equipment to cope with the weed problem, as well as to bend every effort toward developing harvester improvements such that reasonably high field recovery can be accomplished under the many soil conditions encountered throughout the State.

To this end processors and harvester manufacturers alike have pledged their cooperation, and if predictions are in order, it appears that eventual complete mechanization will not be hindered by technical problems.

# Survey of Beet Sugar Agriculture in 1947

P. B. Smith[1]

## Scope of Survey

In both 1946 and 1947 The Beet Sugar Development Foundation conducted surveys designed to obtain information on the various agricultural phases of sugar beet production. Questionnaires were sent out to all of the sugar factory areas in the United States and part of Canada and in 1946 covered 67 percent of the beet acreage. In 1947 the returns were from over 90 percent. From this data certain figures were tabulated based on the grouping of the various sugar production areas into five groups which include those as follows: (1) California; (2) Oregon, Washington, Idaho, western Montana, western Colorado, Arizona, Nevada and Utah; (3) eastern Montana, western North Dakota, Wyoming, western South Dakota, Nebraska, western Kansas, Colorado, New Mexico and Texas; (4) Minnesota, eastern North and South Dakota and Iowa; (5) Wisconsin, Michigan, Illinois, Indiana and Ohio.

In 1947, based on the areas reporting, there would have been 49,161 contracts. This figure does not correspond with the total number of farms raising sugar beets inasmuch as one farm unit may have more than one contract. Generally, however, the two totals will not be very far apart. Information is given as to the average size of contracts by group.

## Explanation of Data

Figures indicate that in 1947 four percent more acreage was planted with processed beet seed as compared with 1946. Decorticated seed was used to some extent in 1947 and only experimentally in 1946. Precision planters increased from a total of 191,280 acres planted in 1946 to 381,518 acres in 1947. This indicates that a great deal of interest was excited in the use of improved drilling equipment.

It will be noted that the row widths vary widely and that probably the different widths have come into use largely because of their suitability to local conditions such as irrigation ease, use of common machinery with other row crops, mechanical harvesting, crop yields and a number of other similar reasons. A large percentage of the California acreage is planted on beds hence the alternate row spacing combinations.

It is interesting to note the tendency to increase the acreage thinned with methods that might tend to save labor—for example, in 1947, 112,235 acres in Canada and United States were long-handled-hoe thinned as compared with 55,531 acres in 1946. This is slightly more than twice as much acreage so handled. In the same way, 16,769 acres were mechani-

[1]Manager, The Beet Sugar Development Foundation, Fort Collins, Colorado.

cally blocked in 1947 as compared with 8,181 acres in 1946, or a substantial gain, on the part of farmers in labor-saving devices. Also it was noted in 1947, that 4,935 acres were finger weeded to either kill weeds or to thin beets, or both, as compared with only 218 acres reported in 1946. This also is good indication of the use by farmers of methods to reduce labor.

In the United States, in 1947, 28.99 percent of the acreage was mechanically harvested as compared with 16.83 percent in 1946. These proportions do not tell the entire story of the use of machines, however. A total 230,415 acres were mechanically harvested in 1947 as compared with only 94,336 acres in 1946. A report lists the acreage and proportions by number of the more important harvesters. Also, it gives figures in detail as to the handling of beet tops.

The report includes some detailed figures as to the fertilizer applications, including the acreage planted, the average rate and the method used. This also is grouped including green manuring as well as barnyard manuring. It is interesting to note that there is an increase of about 5 percent of 1947 acreage covered with commercial fertilizer increased over 1946.

It is planned to continue these Foundation sponsored surveys and it is hoped that after an accumulation of figures from a period of time that certain trends and lessons can be learned from application of agronomic results.

**Statistical Data**—Questionnaires sent out to beet sugar factory districts in United States and Canada. The following summary analysis is based on the returned questionnaires which report on 90 percent of the total harvested acreage for the two countries. The area subdivisions in United States are given in Appendix I.

| | Combined totals for U.S. and Canada | Total for U.S. alone | Total for Canada alone | Total for area 1 | Total for area 2 | Total for area 3 | Total for area 4 | Total for area 5 |
|---|---|---|---|---|---|---|---|---|
| PERCENT OF AREA REPORTING | 90 | 90 | 95 | 89 | 88 | 95 | 100 | 71 |
| GENERAL INFORMATION: | | | | | | | | |
| 1. Number of contracts | 44,245 | 38,941 | 5,304 | 2,182 | 11,736 | 15,133 | 1,265 | 8,625 |
| 2. Average size of contract (acres) | 19.24 | 20.41 | 10.67 | 61.00 | 15.73 | 22.83 | 41.21 | 9.23 |
| 3. Number of contracts | | | | | | | | |
| a. 15 acres or less | 24,098 | 20,214 | 3,884 | 311 | 7,159 | 5,678 | 166 | 6,900 |
| Percent of total number contracts | 54.47 | 51.91 | 73.00 | 14.00 | 61.00 | 38.00 | 13.00 | 80.00 |
| b. 16 through 49 acres | 16,939 | 15,639 | 1,300 | 905 | 4,342 | 8,055 | 698 | 1,639 |
| Percent of total number contracts | 38.28 | 40.16 | 25.00 | 42.00 | 37.00 | 53.00 | 55.00 | 19.00 |
| c. 50 acres or over | 3,208 | 3,088 | 120 | 966 | 235 | 1,400 | 401 | 86 |
| Percent of total number contracts | 7.25 | 7.93 | 2.00 | 44.00 | 2.00 | 9.00 | 32.00 | 1.00 |
| 4. Acres harvested | 851,315 | 794,741 | 56,574 | 133,108 | 184,630 | 345,294 | 52,125 | 79,584 |
| 5. Average yield per acre (tons) | 13.92 | 14.16 | 10.48 | 18.75 | 16.72 | 13.50 | 8.62 | 7.12 |
| 6. Average sucrose percentage | 16.15 | 16.11 | 16.73 | 16.63 | 16.17 | 15.99 | 14.85 | 15.69 |
| SEED INFORMATION: | | | | | | | | |
| 1. Number acres planted with ungraded whole seed | 67,011 | 45,054 | 21,957 | 8,697 | 2,899 | 11,374 | 3,290 | 18,794 |
| Percent of total acres planted | 7.99 | 5.77 | 33.64 | 6.00 | 1.50 | 3.07 | 5.83 | 19.50 |
| 2. Number of acres planted with graded whole seed | 25,521 | 25,521 | ---- | 13,350 | 21 | 2,940 | ---- | 9,210 |
| Percent of total acres planted | 3.12 | 3.39 | ---- | 9.22 | .03 | .79 | ---- | 9.56 |
| 3. Number of acres planted with processed seed | | | | | | | | |
| a. Segmented | 812,860 | 769,553 | 43,307 | 107,452 | 186,665 | 355,584 | 53,105 | 66,747 |
| Percent of total acres planted | 86.73 | 88.50 | 66.36 | 74.19 | 98.45 | 95.96 | 94.17 | 69.26 |
| b. Decorticated | 15,980 | 15,980 | ---- | 15,340 | ---- | 640 | ---- | ---- |
| Percent of total acres planted | 1.96 | 2.12 | ---- | 10.59 | ---- | .18 | ---- | ---- |
| c. Pellets | 1,644 | 1,644 | ---- | ---- | 17 | 3 | ---- | 1,624 |
| Percent of total acres planted | .02 | .22 | ---- | ---- | .02 | ---- | ---- | 1.68 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PLANTER INFORMATION:** | | | | | | | | |
| 1. Number acres planted with precision planter | 405,265 | 381,518 | 23,747 | 22,067 | 114,037 | 170,590 | 14,743 | 60,081 |
| Percent of total acres planted | 43.91 | 44.48 | 36.39 | 15.24 | 60.15 | 46.04 | 26.14 | 62.34 |
| 2. Number acres planted with non-precision planter | 517,753 | 476,236 | 41,517 | 122,772 | 75,567 | 199,951 | 41,652 | 36,294 |
| Percent of total acres planted | 56.09 | 55.52 | 63.61 | 84.76 | 39.85 | 53.96 | 73.86 | 37.66 |
| 3. Number planters calculated for 100 percent report | 15,148 | 13,585 | 1,481 | 1,413 | 2,295 | 7,440 | 710 | 1,648 |
| John Deere Nos. 4, 12, 112 | | | | | | | | |
| Percent of total number | 4.52 | 4.29 | 6.32 | ----- | 14.08 | 4.50 | ----- | 2.74 |
| Percent of total acres planted | 4.10 | 3.98 | 5.92 | ----- | 15.48 | 4.05 | ----- | 1.87 |
| John Deere Nos. 7, 10, 11, 32 Conv. | | | | | | | | |
| Percent of total number | 5.64 | 6.10 | 1.99 | 1.10 | 12.97 | 7.74 | ----- | ----- |
| Percent of total acres planted | 4.96 | 4.79 | 7.52 | .66 | 12.15 | 6.68 | ----- | ----- |
| John Deere Nos. 11, 21, 55 | | | | | | | | |
| Percent of total number | 9.50 | 8.10 | 20.54 | 1.67 | 3.78 | 8.66 | ----- | 19.91 |
| Percent of total acres planted | 10.00 | 9.26 | 19.00 | 2.64 | 4.11 | 8.22 | ----- | 33.14 |
| John Deere Nos. 22, 21, 55 Conv. | | | | | | | | |
| Percent of total number | 10.45 | 11.02 | 6.04 | 2.78 | 11.42 | 11.93 | .70 | 20.26 |
| Percent of total acres planted | 10.90 | 10.68 | 14.03 | 5.26 | 6.86 | 12.80 | 1.73 | 19.22 |
| John Deere No. 18 | | | | | | | | |
| Percent of total number | 2.84 | 3.14 | .57 | 12.16 | .22 | 2.70 | .28 | ----- |
| Percent of total acres planted | 4.50 | 4.85 | .85 | 16.72 | .19 | 3.22 | .27 | ----- |
| John Deere No. 18 Conv. | | | | | | | | |
| Percent of total number | 2.80 | 3.03 | 1.07 | .48 | 4.55 | 2.80 | 12.68 | ----- |
| Percent of total acres planted | 3.20 | 3.33 | 2.15 | .84 | 2.31 | 4.18 | 11.25 | ----- |
| John Deere No. 64 | | | | | | | | |
| Percent of total number | 1.62 | 1.52 | 2.42 | ----- | ----- | .96 | ----- | 8.63 |
| Percent of total acres planted | 1.91 | 1.80 | 3.55 | ----- | ----- | 1.65 | ----- | 7.64 |
| John Deere No. 66 | | | | | | | | |
| Percent of total number | 2.82 | 3.12 | .43 | .16 | 1.66 | 2.89 | 10.42 | 4.44 |
| Percent of total acres planted | 4.61 | 4.98 | .83 | .33 | 2.37 | 5.04 | 18.11 | 6.24 |
| Rassmann | | | | | | | | |
| Percent of total number | 1.02 | 1.13 | .14 | ----- | .22 | .65 | 9.15 | 1.20 |
| Percent of total acres planted | 1.32 | 1.42 | .16 | ----- | .40 | .44 | 14.85 | .28 |
| Lindeman or Cobbley (on sleds or frames) | | | | | | | | |
| Percent of total number | 1.93 | 2.15 | .14 | 3.18 | 19.40 | .21 | ----- | .77 |
| Percent of total acres planted | 2.62 | 2.84 | .40 | 4.26 | 14.77 | .55 | ----- | .70 |
| Oliver-Plate and internal feed | | | | | | | | |
| Percent of total number | 4.75 | 5.06 | 2.27 | 2.38 | 3.99 | 3.10 | 13.53 | 15.47 |
| Percent of total acres planted | 4.77 | 4.66 | 6.38 | 4.76 | 5.44 | 2.31 | 13.26 | 7.81 |

| | Combined totals for U.S. and Canada | Total for U.S. alone | Total for Canada alone | Total for area 1 | Total for area 2 | Total for area 3 | Total for area 4 | Total for area 5 |
|---|---|---|---|---|---|---|---|---|
| **Moline (monitor and tractor mounted)** | | | | | | | | |
| Percent of total number | 13.58 | 14.74 | 4.41 | 2.15 | ---- | 19.77 | 8.73 | 12.91 |
| Percent of total acres planted | 9.55 | 9.59 | 9.48 | 2.20 | ---- | 14.97 | 6.26 | 10.33 |
| **Case, old** | | | | | | | | |
| Percent of total number | 1.08 | 1.21 | .07 | ---- | ---- | 1.47 | ---- | 2.56 |
| Percent of total acres planted | .90 | .97 | .09 | ---- | ---- | 1.17 | ---- | 3.12 |
| **Case, new or converted to machine plate** | | | | | | | | |
| Percent of total number | 1.68 | 1.89 | ---- | .08 | .22 | 2.93 | ---- | ---- |
| Percent of total acres planted | 1.53 | 1.69 | ---- | .27 | .43 | 3.24 | ---- | ---- |
| **Planet, Jr.** | | | | | | | | |
| Percent of total number | 10.11 | 11.39 | ---- | 66.06 | 2.99 | 5.76 | ---- | ---- |
| Percent of total acres planted | 11.30 | 12.31 | ---- | 50.20 | 3.03 | 4.69 | ---- | ---- |
| **Milton** | | | | | | | | |
| Percent of total number | .68 | .48 | 2.27 | ---- | ---- | .75 | ---- | ---- |
| Percent of total acres planted | .79 | .56 | 3.51 | ---- | ---- | 1.13 | ---- | ---- |
| **I. H. C. No. 40** | | | | | | | | |
| Percent of total number | 3.78 | 4.12 | 1.07 | 3.58 | 4.66 | 4.44 | 4.23 | 2.31 |
| Percent of total acres planted | 5.29 | 5.58 | 2.30 | 6.05 | 8.38 | 5.44 | 5.51 | 3.00 |
| **I. H. C. No. 40, converted to smooth tube** | | | | | | | | |
| Percent of total number | 2.64 | 2.93 | .28 | .32 | 5.65 | 3.83 | ---- | ---- |
| Percent of total acres planted | 2.79 | 3.00 | .81 | .15 | 6.00 | 4.66 | ---- | ---- |
| **I. H. C. No. 42** | | | | | | | | |
| Percent of total number | 2.78 | 3.13 | ---- | 1.75 | 2.55 | 2.97 | 12.39 | .43 |
| Percent of total acres planted | 4.83 | 5.28 | ---- | 2.93 | 7.88 | 4.86 | 18.25 | .52 |
| **I. H. C. No. 42, converted to smooth tube** | | | | | | | | |
| Percent of total number | .92 | 1.04 | ---- | .48 | 2.77 | 1.19 | ---- | ---- |
| Percent of total acres planted | 1.26 | 1.40 | ---- | .87 | 3.38 | 1.73 | ---- | ---- |
| **Others** | | | | | | | | |
| Percent of total number | 3.10 | 3.49 | ---- | .08 | .78 | 2.18 | 27.89 | 2.39 |
| Percent of total acres planted | 2.13 | 2.30 | ---- | .10 | .54 | 2.26 | 10.51 | 3.14 |
| **4. Seeding rate most common to your area** | | | | | | | | |
| Whole | 12.40 | 12.50 | 10.00 | 13.00 | 15.00 | 11.00 | ---- | 10.71 |
| Segmented | 4.80 | 4.84 | 4.30 | 4.90 | 4.10 | 5.10 | 6.50 | 3.63 |

**PLANTER INFORMATION**—Continued

5. List approximate acreages planted at various row width:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a. 18 inch | 37,961 | 36,972 | 989 | 97 | ---- | 700 | 36,149 | 26 |
| Percent of total acres planted | 4.11 | 4.31 | 1.51 | .01 | ---- | .19 | 64.10 | .03 |
| b. 20 inch | 331,321 | 321,695 | 9,626 | 31,673 | 79,310 | 199,638 | 11,054 | 20 |
| Percent of total acres planted | 35.86 | 37.50 | 14.75 | 21.97 | 41.83 | 53.88 | 19.60 | .02 |
| c. 21 inch | 225 | 225 | ---- | ---- | ---- | 225 | ---- | ---- |
| Percent of total acres planted | .03 | .03 | ---- | ---- | ---- | .06 | ---- | ---- |
| d. 22 inch | 279,092 | 239,303 | 39,789 | 1,736 | 85,473 | 128,475 | 4,820 | 18,799 |
| Percent of total acres planted | 30.21 | 27.90 | 60.97 | 1.20 | 45.08 | 34.67 | 8.55 | 19.51 |
| e. 24 inch | 48,344 | 36,794 | 11,550 | 1,037 | 15,696 | 6,367 | 4,152 | 9,542 |
| Percent of total acres planted | 5.24 | 4.29 | 17.70 | .72 | 8.28 | 1.72 | 7.36 | 9.90 |
| f. 26 inch | 9,222 | 8,952 | 270 | 647 | 620 | 4,944 | 50 | 2,691 |
| Percent of total acres planted | 1.00 | 1.04 | .41 | .45 | .33 | 1.33 | .09 | 2.79 |
| g. 28 inch | 80,551 | 77,951 | 2,600 | 8,011 | 374 | 4,319 | ---- | 65,247 |
| Percent of total acres planted | 8.73 | 9.09 | 3.98 | 5.53 | .20 | 1.17 | ---- | 67.70 |
| h. 30 inch | 12,555 | 12,165 | 390 | 9,670 | 540 | 1,755 | 150 | 50 |
| Percent of total acres planted | 1.36 | 1.42 | .60 | 6.68 | .28 | .47 | .27 | .05 |
| i. 32 inch | 7,109 | 7,079 | 30 | 6,991 | 74 | 14 | ---- | ---- |
| Percent of total acres planted | .77 | .83 | .05 | 4.82 | .04 | .01 | ---- | ---- |
| j. 34 inch | 6,891 | 6,891 | ---- | 6,891 | ---- | ---- | ---- | ---- |
| Percent of total acres planted | .75 | .80 | ---- | 4.75 | ---- | ---- | ---- | ---- |
| k. 36 inch | 170 | 170 | ---- | ---- | ---- | 170 | ---- | ---- |
| Percent of total acres planted | .02 | .02 | ---- | ---- | ---- | .05 | ---- | ---- |
| l. 38 inch | 206 | 206 | ---- | ---- | ---- | 206 | ---- | ---- |
| Percent of total acres planted | .03 | .03 | ---- | ---- | ---- | .06 | ---- | ---- |
| m. 40 inch | 388 | 388 | ---- | ---- | ---- | 388 | ---- | ---- |
| Percent of total acres planted | .05 | .05 | ---- | ---- | ---- | .10 | ---- | ---- |
| n. 12 x 30 inch | 12,465 | 12,465 | ---- | 12,465 | ---- | ---- | ---- | ---- |
| Percent of total acres planted | 1.35 | 1.45 | ---- | 8.61 | ---- | ---- | ---- | ---- |

| | Combined totals for U.S. and Canada | Total for U.S. alone | Total for Canada alone | Total for area 1 | Total for area 2 | Total for area 3 | Total for area 4 | Total for area 5 |
|---|---|---|---|---|---|---|---|---|
| o. 12 x 32 inch | 125 | 125 | ---- | 125 | ---- | ---- | ---- | ---- |
| Percent of total acres planted | .02 | .02 | ---- | .01 | ---- | ---- | ---- | ---- |
| p. 14 x 26 inch | 46,202 | 46,202 | ---- | 45,852 | 350 | ---- | ---- | ---- |
| Percent of total acres planted | 5.01 | 5.39 | ---- | 31.77 | .18 | ---- | ---- | ---- |
| q. 14 x 28 inch | 4,468 | 4,468 | ---- | 4,468 | ---- | ---- | ---- | ---- |
| Percent of total acres planted | .48 | .52 | ---- | 3.08 | ---- | ---- | ---- | ---- |
| r. 16 x 24 inch | 10,119 | 10,119 | ---- | 4,884 | 4,306 | 929 | ---- | ---- |
| Percent of total acres planted | 1.10 | 1.18 | ---- | 3.37 | 2.27 | .25 | ---- | ---- |
| s. 18 x 22 inch | 18,304 | 18,304 | ---- | ---- | 130 | 18,174 | ---- | ---- |
| Percent of total acres planted | 1.98 | 2.13 | ---- | ---- | .07 | 4.90 | ---- | ---- |
| t. 18 x 23 inch | 47 | 47 | ---- | ---- | ---- | 47 | ---- | ---- |
| Percent of total acres planted | .01 | .01 | ---- | ---- | ---- | .01 | ---- | ---- |
| u. 18 x 24 inch | 700 | 700 | ---- | ---- | 700 | ---- | ---- | ---- |
| Percent of total acres planted | .08 | .09 | ---- | ---- | .37 | ---- | ---- | ---- |
| v. 20 x 22 inch | 4,190 | 4,190 | ---- | ---- | ---- | 4,190 | ---- | ---- |
| Percent of total acres planted | .45 | .49 | ---- | ---- | ---- | 1.13 | ---- | ---- |
| w. 20 x 24 inch | 2,097 | 2,097 | ---- | 117 | 1,980 | ---- | ---- | ---- |
| Percent of total acres planted | .23 | .24 | ---- | .01 | 1.04 | ---- | ---- | ---- |
| x. 18 x 26 inch | 50 | 50 | ---- | ---- | 50 | ---- | ---- | ---- |
| Percent of total acres planted | .01 | .01 | ---- | ---- | .03 | ---- | ---- | ---- |
| y. 20 x 40 inch | 733 | 733 | 20 | 713 | ---- | ---- | ---- | ---- |
| Percent of total acres planted | .09 | .10 | .03 | .49 | ---- | ---- | ---- | ---- |
| z. 24 x 32 inch | 20 | 20 | ---- | ---- | ---- | ---- | 20 | ---- |
| Percent of total acres planted | ---- | ---- | ---- | ---- | ---- | ---- | .03 | ---- |
| Others | 9,462 | 9,462 | ---- | 9,462 | ---- | ---- | ---- | ---- |
| Percent of total acres planted | 1.03 | 1.10 | ---- | 6.53 | ---- | ---- | ---- | ---- |
| 6. Number of acres planted with ridge covering | 5,111 | 4,871 | 240 | ---- | 694 | 4,177 | ---- | ---- |
| Percent of total acres planted | .57 | .57 | .37 | ---- | .37 | 1.13 | ---- | ---- |
| 7. Number of acres treated with a soil fumigant prior to planting | 3,574 | 3,549 | 25 | 2,575 | 970 | 4 | ---- | ---- |
| Percent of total acres planted | .37 | .40 | .04 | 1.78 | .51 | ---- | ---- | ---- |

Statistical Data—Continued

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **THINNING OPERATIONS:** | | | | | | | | |
| 1. Number of acres hand blocked and thinned (short-handle hoe) | 707,361 | 679,196 | 28,165 | 129,643 | 171,806 | 300,446 | 23,605 | 53,696 |
| Percent of total acres thinned | 81.11 | 83.25 | 49.76 | 97.35 | 91.34 | 85.08 | 41.91 | 63.05 |
| 2. Number of acres thinned with long-handled hoe | 112,235 | 84,956 | 27,639 | 2,252 | 13,202 | 38,101 | ---- | 31,401 |
| Percent of total acres thinned | 12.87 | 10.41 | 48.83 | 1.69 | 7.02 | 10.79 | ---- | 36.88 |
| 3. Number of acres mechanically blocked | 16,769 | 16,204 | 565 | 605 | 500 | 5,317 | 9,782 | ---- |
| Percent of total acres thinned | 1.92 | 1.99 | 1.00 | .45 | .27 | 1.51 | 17.37 | ---- |
| 4. Number of acres mechanically blocked then cross cultivated | 22,298 | 22,163 | 135 | ---- | ---- | 17 | 22,146 | ---- |
| Percent of total acres thinned | 2.56 | 2.72 | .24 | ---- | ---- | ---- | 39.32 | ---- |
| 5. Number of acres planted at low-seeding rate and hence requiring no thinning | 1,499 | 1,499 | ---- | ---- | 1,310 | 174 | ---- | 15 |
| Percent of total acres thinned | .17 | .18 | ---- | ---- | .70 | .05 | ---- | .02 |
| 6. Number of acres mechanically cross thinned | 680 | 680 | ---- | ---- | 260 | 134 | 276 | 10 |
| Percent of total acres thinned | .08 | .08 | ---- | ---- | .14 | .04 | .49 | .01 |
| 7. Number of acres mechanically down-the-row thinned | 1,448 | 1,368 | 80 | 685 | 170 | 513 | ---- | ---- |
| Percent of total acres thinned | .17 | .17 | .14 | .51 | .09 | .15 | ---- | ---- |
| 8. Number of acres mechanically down-the-row blocked | 3,181 | 3,171 | 10 | ---- | 257 | 2,914 | ---- | ---- |
| Percent of total acres thinned | .36 | .39 | .02 | ---- | .14 | .83 | ---- | ---- |
| 9. Number of acres thinned with harrow or finger weeder | 1,567 | 1,567 | ---- | ---- | 339 | 1,064 | 164 | ---- |
| Percent of total acres thinned | .18 | .19 | ---- | ---- | .18 | .30 | .29 | ---- |
| 10. Number of acres on which finger weeder used to either kill weeds, to thin beets or both | 4,935 | 4,935 | ---- | ---- | 231 | 4,404 | 300 | ---- |
| Percent of total acres thinned | .57 | .60 | ---- | ---- | .12 | 1.25 | .53 | ---- |
| 11. Number of beet acres on which chemical weed control practiced | 90 | 85 | 5 | ---- | ---- | ---- | 50 | 30 |
| Percent of total acres thinned | .01 | .01 | .01 | ---- | ---- | ---- | .09 | .04 |
| a. Type of chemical | Salt | Salt | Salt | ---- | ---- | ---- | Salt | Salt |
| b. Rate per acre | 250#/A | 250#/A | 250#/A | ---- | ---- | ---- | 200#/A | 300#/A |

| | Combined totals for U.S. and Canada | Total for U.S. alone | Total for Canada alone | Total for area 1 | Total for area 2 | Total for area 3 | Total for area 4 | Total for area 5 |
|---|---|---|---|---|---|---|---|---|
| **HARVESTING OPERATIONS:** | | | | | | | | |
| 1. Number of acres hand harvested | 617,572 | 564,326 | 53,246 | 47,214 | 133,869 | 267,200 | 48,342 | 67,701 |
| Percent of total harvest acres | 72.54 | 71.01 | 94.12 | 35.47 | 72.51 | 77.38 | 92.74 | 85.07 |
| 2. Number of acres mechanically harvested | 233,743 | 230,415 | 3,328 | 85,894 | 50,761 | 78,094 | 3,783 | 11,883 |
| Percent of total harvest acres | 27.46 | 28.99 | 5.88 | 64.53 | 27.49 | 22.62 | 7.26 | 14.93 |
| 3. Number of harvesters calculated for 100 percent report | 3,790 | 3,688 | 102 | 453 | 1,088 | 1,793 | 65 | 289 |
| a. International—Number | | | | | | | | |
| Percent of total harvesters | 24.30 | 24.20 | 27.84 | 6.95 | 20.56 | 30.12 | 87.69 | 5.85 |
| Percent of total mechanical harvested acres | 22.50 | 22.28 | 36.93 | 5.39 | 28.35 | 37.44 | 86.10 | 4.50 |
| b. Marbeet, Sr.—Number | | | | | | | | |
| Percent of total harvesters | 6.15 | 6.33 | ---- | 50.12 | .63 | .18 | ---- | ---- |
| Percent of total mechanical harvested acres | 25.35 | 25.74 | ---- | 64.39 | 1.98 | .26 | ---- | ---- |
| c. Marbeet, Jr.—Number | | | | | | | | |
| Percent of total harvesters | 5.13 | 5.28 | ---- | 41.44 | ---- | .53 | ---- | ---- |
| Percent of total mechanical harvested acres | 11.59 | 11.76 | ---- | 29.39 | ---- | .61 | ---- | ---- |
| d. John Deere—Number | | | | | | | | |
| Percent of total harvesters | 48.43 | 48.26 | 53.61 | ---- | 59.40 | 61.01 | ---- | .49 |
| Percent of total mechanical harvested acres | 28.75 | 28.42 | 50.72 | ---- | 51.63 | 53.78 | ---- | .09 |
| e. Kiest—Number | | | | | | | | |
| Percent of total harvesters | 4.98 | 4.80 | 11.34 | ---- | 8.25 | 4.76 | ---- | ---- |
| Percent of total mechanical harvested acres | 2.38 | 2.35 | 4.39 | ---- | 6.10 | 3.53 | ---- | ---- |
| f. Scott-Urschel—Number | | | | | | | | |
| Percent of total harvesters | 8.30 | 8.43 | 4.12 | ---- | 3.44 | 3.05 | 7.69 | 93.17 |
| Percent of total mechanical harvested acres | 7.69 | 7.69 | 7.57 | ---- | 4.63 | 4.24 | 10.57 | 95.11 |
| g. Others—Number | | | | | | | | |
| Percent of total harvesters | 2.71 | 2.70 | 3.09 | 1.49 | 7.72 | .35 | 4.62 | .49 |
| Percent of total mechanical harvested acres | 1.74 | 1.76 | .39 | .83 | 7.31 | .14 | 3.33 | .30 |
| 4. Number of acres on which a "beater-topper" was used | 19,666 | 19,666 | ---- | 190 | 19,463 | 13 | ---- | ---- |
| 5. Number of "beater-toppers" in area | 422 | 422 | 2 | 4 | 414 | 2 | ---- | ---- |
| 6. Number of loaders used in area | 9,014 | 8,603 | 411 | 2 | 1,580 | 5,983 | 454 | 584 |
| 7. Approximate harvested acreage handled with loaders | 435,920 | 413,672 | 22,248 | 340 | 41,188 | 279,236 | 46,806 | 46,102 |
| Percent of total harvested acres | 51.21 | 52.05 | 39.33 | .26 | 22.31 | 80.87 | 89.80 | 57.93 |
| **BEET-TOP UTILIZATION:** | | | | | | | | |
| Actual acreage and percentage of harvested acreage. Note that since certain methods of utilization permit the listing of the same acreage under more than one heading the total of the percentage figures will be greater than 100. | | | | | | | | |
| 1. Left in field without windrowing or piling | 247,750 | 223,929 | 23,821 | 56,016 | 38,031 | 63,940 | 37,012 | 28,930 |
| Percent of total harvested acreage | 29.10 | 28.18 | 42.11 | 42.08 | 20.60 | 18.52 | 71.01 | 36.35 |

Statistical Data—Continued

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **HARVESTING OPERATIONS**—Continued | | | | | | | | |
| 2. Windrowed and left in field | 140,712 | 123,180 | 17,532 | 1,895 | 5,571 | 98,058 | 6,750 | 10,906 |
| Percent of total harvested acreage | 16.53 | 15.50 | 30.99 | 1.42 | 3.02 | 28.40 | 12.95 | 13.70 |
| 3. Pastured immediately after harvest | 400,950 | 371,452 | 29,498 | 64,935 | 129,510 | 131,914 | 10,312 | 34,781 |
| Percent of total harvested acreage | 47.10 | 46.74 | 52.14 | 48.78 | 70.15 | 38.20 | 19.78 | 43.70 |
| 4. Plowed under shortly after harvest for fertility value | 54,266 | 52,726 | 1,540 | 36,369 | 5,108 | 3,873 | 2,626 | 4,750 |
| Percent of total harvested acreage | 6.37 | 6.63 | 2.72 | 27.32 | 2.77 | 1.12 | 5.04 | 5.97 |
| 5. Piled in small piles in the field | 167,608 | 156,692 | 10,916 | 1,732 | 3,763 | 139,284 | 7,995 | 3,918 |
| Percent of total harvested acreage | 19.69 | 19.72 | 19.30 | 1.30 | 2.04 | 40.34 | 15.34 | 4.92 |
| 6. Stacked dry | 22,471 | 22,371 | 100 | ---- | 100 | 21,484 | 112 | 675 |
| Percent of total harvested acreage | 2.64 | 2.81 | .18 | ---- | .05 | 6.22 | .21 | .85 |
| 7. Siloed: | | | | | | | | |
| a. Above ground | 2,787 | 2,452 | 335 | ---- | 146 | 1,750 | 86 | 470 |
| Percent of total harvested acreage | .27 | 31 | .59 | -- | .08 | .51 | .16 | .59 |
| b. In pits | 3,022 | 2,922 | 100 | 320 | 640 | 1,852 | ---- | 110 |
| Percent of total harvested acreage | .35 | .37 | .18 | .24 | .35 | .54 | ---- | .14 |
| 8. Dehydrated | 40 | 40 | ---- | ---- | 40 | ---- | ---- | ---- |
| Percent of total harvested acreage | ---- | ---- | ---- | ---- | .02 | ---- | ---- | ---- |
| 9. Hauled off field and fed as green feed | 49,173 | 46,448 | 2,725 | 1,932 | 1,491 | 20,509 | 5,080 | 17,436 |
| Percent of total harvested acreage | 5.78 | 5.84 | 4.82 | 1.45 | .81 | 5.94 | 9.75 | 21.91 |
| 10. Pastured before harvest | 2,445 | 2,445 | ---- | ---- | ---- | 2,445 | ---- | ---- |
| Percent of total harvested acreage | .31 | .33 | ---- | ---- | ---- | .71 | ---- | ---- |
| 11. Other | 300 | 300 | ---- | ---- | ---- | ---- | ---- | 300 |
| Percent of total harvested acreage | .04 | .04 | ---- | ---- | ---- | ---- | ---- | .40 |
| **FERTILIZERS:** | | | | | | | | |
| Percentage of planted acres, average rate and method of application. Since some acreage has had more than one type of fertilizer application, the total percentages of planted acres will exceed 100 percent. | | | | | | | | |
| 1. Manured for beets—percentage of planted acres | 31.59 | 33.42 | 10.42 | 2.58 | 45.33 | 45.14 | 17.24 | 33.72 |
| 2. Green-manured for beets—percentage of planted acres | 12.22 | 12.26 | 11.69 | 10.20 | 4.76 | 5.12 | 61.15 | 20.81 |
| 3. Acres on which complete commercial fertilizer added—percentage of planted acres | 27.47 | 25.63 | 48.75 | 19.23 | 9.55 | 11.10 | 43.40 | 94.81 |
| a. Average rate | 250.00 | 260.00 | 195.00 | 558.00 | 151.00 | 151.00 | 159.00 | 254.00 |
| b. Method of application (percent) | | | | | | | | |
| A | 3.88 | 7.78 | ---- | 25.00 | 2.50 | 1.77 | 6.70 | 2.91 |
| B | 2.06 | 3.12 | 1.00 | 3.75 | 2.50 | 7.54 | 1.00 | .83 |
| C | 11.05 | 12.11 | 10.00 | 12.50 | 7.50 | 26.33 | ---- | 14.50 |
| D | 38.64 | 26.21 | 51.00 | ---- | 10.00 | 5.76 | 90.27 | 27.92 |
| E | 28.08 | 18.16 | 38.00 | ---- | 15.00 | 21.38 | 1.70 | 53.59 |
| F | 4.10 | 8.20 | ---- | 31.25 | 5.00 | 4.46 | .33 | .25 |
| G | 11.44 | 22.88 | ---- | 27.50 | 55.00 | 31.69 | ---- | ---- |
| H | .46 | .92 | ---- | ---- | ---- | .46 | ---- | ---- |
| I | .28 | .59 | ---- | ---- | 2.50 | .46 | ---- | ---- |
| J | .01 | .03 | ---- | ---- | ---- | .15 | ---- | ---- |

| | Combined totals for U.S. and Canada | Total for U.S. alone | Total for Canada alone | Total for area 1 | Total for area 2 | Total for area 3 | Total for area 4 | Total for area 5 |
|---|---|---|---|---|---|---|---|---|
| 4. Acres on which commercial phosphate added—percentage of planted acres | 44.15 | 43.95 | 46.45 | 24.30 | 66.32 | 53.98 | 69.25 | .52 |
| a. Average rate | 160.00 | 166.00 | 92.00 | 629.00 | 120.00 | 110.00 | 100.00 | 400.00 |
| b. Method of application (percent) | | | | | | | | |
| A | 1.88 | 3.77 | ---- | ---- | 16.57 | 2.30 | ---- | ---- |
| B | 2.98 | 5.97 | ---- | 8.68 | 12.28 | 8.80 | ---- | ---- |
| C | 38.87 | 27.75 | 50.00 | 4.00 | 3.00 | 31.75 | 100.00 | 100.00 |
| D | 34.30 | 28.53 | 40.00 | ---- | 16.45 | 26.25 | ---- | ---- |
| E | 10.40 | 10.81 | 10.00 | 16.66 | 11.99 | 25.35 | ---- | ---- |
| F | 4.65 | 9.31 | ---- | 38.50 | 8.00 | .05 | ---- | ---- |
| G | 5.23 | 10.47 | ---- | 32.16 | 17.00 | 3.20 | ---- | ---- |
| H | .06 | .12 | ---- | ---- | .57 | .05 | ---- | ---- |
| I | 1.53 | 3.06 | ---- | ---- | 13.14 | 2.20 | ---- | ---- |
| J | .10 | .21 | ---- | ---- | 1.00 | .05 | ---- | ---- |
| 5. Acres on which commercial nitrogen added—percentage of planted acres | 25.46 | 23.68 | 46.00 | 57.92 | 36.41 | 16.94 | .53 | .52 |
| a. Average rate | 225.00 | 247.00 | 91.00 | 378.00 | 126.00 | 131.00 | 125.00 | 300.00 |
| b. Method of application (percent) | | | | | | | | |
| A | 1.31 | 2.63 | ---- | ---- | 13.16 | ---- | ---- | ---- |
| B | 1.38 | 2.79 | ---- | 9.50 | 4.42 | .05 | ---- | ---- |
| C | 29.68 | 21.73 | 37.50 | 2.50 | 2.42 | 3.75 | ---- | 100.00 |
| D | 20.34 | .67 | 40.00 | .50 | ---- | 2.85 | ---- | ---- |
| E | 6.17 | 2.34 | 10.00 | ---- | 2.57 | 9.15 | ---- | ---- |
| F | 2.86 | 5.72 | ---- | 6.25 | 17.71 | 4.64 | ---- | ---- |
| G | 34.45 | 56.49 | 12.50 | 67.50 | 53.87 | 61.01 | 100.00 | ---- |
| H | 3.52 | 7.05 | ---- | 13.75 | 3.00 | 18.50 | ---- | ---- |
| I | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| J | .29 | .58 | ---- | ---- | 2.85 | .05 | ---- | ---- |

Statistical Data—Continued

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6. Acres on which commercial potash added alone—percentage of planted acres | .20 | .22 | ---- | .22 | ---- | .37 | ---- | ---- |
| a. Average rate | 99.00 | 99.00 | ---- | 20.00 | ---- | 118.00 | ---- | ---- |
| b. Method of application (percent) | | | | | | | | |
| A | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| B | 2.91 | 2.91 | ---- | ---- | ---- | 5.83 | ---- | ---- |
| C | 13.33 | 13.33 | ---- | ---- | ---- | 26.66 | ---- | ---- |
| D | 7.49 | 7.49 | ---- | ---- | ---- | 14.99 | ---- | ---- |
| E | 4.35 | 4.35 | ---- | ---- | ---- | 8.69 | ---- | ---- |
| F | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| G | 67.75 | 67.75 | ---- | 100.00 | ---- | 35.50 | ---- | ---- |
| H | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| I | 4.17 | 4.17 | ---- | ---- | ---- | 8.33 | ---- | ---- |
| J | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 7. Acres on which commercial minor elements added—percentage of planted acres | .43 | .46 | ---- | .02 | ---- | .22 | ---- | 2.75 |
| a. Average rate | 18.00 | 18.00 | ---- | 20.00 | ---- | 25.00 | ---- | 16.00 |
| b. Method of application (percent) | | | | | | | | |
| A | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| B | 16.67 | 16.67 | ---- | ---- | ---- | ---- | ---- | 50.00 |
| C | 4.65 | 4.65 | ---- | ---- | ---- | 14.00 | ---- | ---- |
| D | 16.00 | 16.00 | ---- | ---- | ---- | 38.00 | ---- | 10.00 |
| E | 22.34 | 22.34 | ---- | ---- | ---- | 27.00 | ---- | 40.00 |
| F | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| G | 38.67 | 38.67 | ---- | 100.00 | ---- | 16.00 | ---- | ---- |
| H | 1.67 | 1.67 | ---- | ---- | ---- | 5.00 | ---- | ---- |
| I | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| J | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

KEY TO METHOD OF APPLICATION:

A—Broadcast then plowed under.
B—Broadcast then disced or worked into soil after plowing.
C—Drilled in with combination grain and fertilizer drill.
D—With planter in seed furrow.
E—With planter alongside of row.
F—Side-dressed immediately after planting.
G—Side-dressed after thinning.
H—Applied in irrigation water.
I—Phosphate placed on manure in feedlot or spreader.
J—Other (list method and percentage).

# Changing the Beet Root Shape to Conform to Mechanical Harvesting

P. B. Smith[1]

For some time people in the industry have been considering the necessity of developing a new type root particularly adapted to mechanical beet harvesting. A test was conducted this past fall at Fort Collins, Colorado, with two types of roots, harvested with a Marbeet "Midget" harvester. All of those who witnessed the test were very optimistic as to the possibilities of changing the shape of the beet and its place in our mechanization of the beet crop.

The two varieties compared were one which included the present standard commercial root type, which has a long tapering root form, with a new, more blunt-shaped beet. As many farmers and agriculturists all over the country have remarked, this shape does not conform to fast pulling of beets as the tap roots break off in unfavorable soil conditions, particularly when the roots are brittle. Very little has been done about

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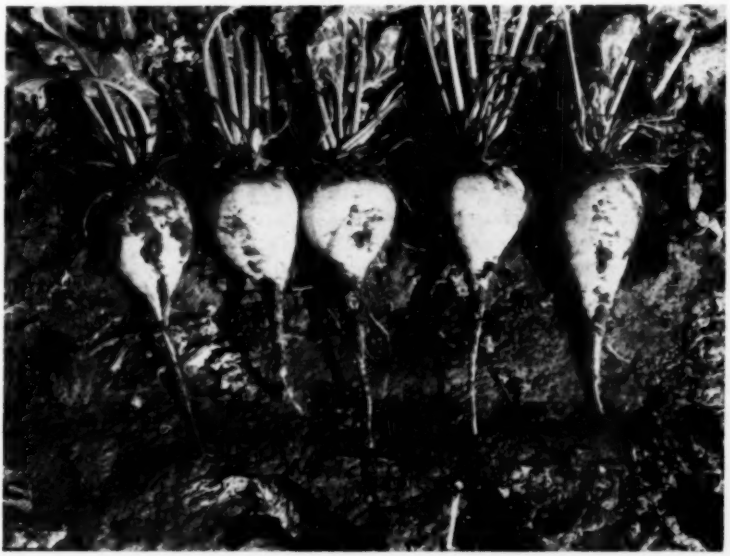
finding out how much of the root is left in the soil with mechanical harvesting as compared with ordinary beet pullers. The second variety compared has a root that is heart shaped, has a small crown but carries the weight up closer to the surface of the soil. The variety used in the test was a four-generation selection from a cross between a red garden beet and a leaf spot-resistant sugar beet U. S. 200 x 215. This development required 8 years to reach the hybrid beet in the comparison. Because of the hybrid character, the beet was also very uniform as to the size and shape with practically all of the beets having the appearance of being turned out of a single mold.



The beets were in 16-row plots 250 feet long and were adjacent in the same field so that the soil type and character of other conditions were as similar as it was possible to obtain. The accompanying photographs show in No. 1, the type of root compared as a check with that in photograph No. 2 as the new variety of root for mechanical harvesting. It is not important that this particular variety be the one used in mechanical harvesting. We are merely stressing the importance or need of changing our present standards of root selection to conform to more modern equipment. Incidentally, in the test the hybrid beet averaged 15.47 tons as compared with the conventional of 12.3 tons.

Actual comparisons on a percentage basis are given in table 1:

Table 1.

| | Standard conventional | Machine hybrid |
|---|---|---|
| Percent weight of beets lost from machine | 3.6 | 2.5 |
| Percent weight of total beets left in ground | 5.0 | 0.0 |
| Percent weight of beet tissue on tops (loss) | 0.5 | 1.7 |
| Percent top tare of harvested beets | 6.1 | 3.4 |

If you translate the figures reported in the table with actual tonnages the differences are much more significant in favor of the new type root. Assuming an average crop of 13 tons per acre, the losses represented with the conventional type root, including losses from the machine and in the ground, amounted to 1.18 tons per acre. Comparing this with the losses on the same acreage yield with the mechanical root of .54 ton, we have only 46 percent as much lost root. This does not include the amount of top tare. We feel that it is very important also that the nature of receiving beets, with the more vigorous screening now employed at receiving stations and the subsequent rather rough handling in rock separation wheels, beet washers at the factory and other mechanical devices, that the new type root, being more round in character, will not sustain the tailings losses which at some factories now runs as high as 5 to 10 percent. These losses have been too much ignored in the past, but mechanical operations, including Athey loaders, clam shells and other devices lay stress on the importance that plant breeders are going to play in developing a better shaped root.

## Conclusions

Even though the results reported were entirely inadequate from a statistical standpoint, they are so outstanding in this first initial test that we are insisting that considerable additional work be done to compare all phases surrounding the development of the new shaped root for mechanical production. As compared with the conventional tapered roots, the new type has the following advantages:

1. Because of its shorter tap root, there is much less draft on the tractor as the beets grow shallower and it is not necessary to set puller points as deep.

2. Less root breakage in the ground.

3. Less losses of roots in machine harvesting.

4. Less total top tare due to greater uniformity of beets in the manner in which they grow out of the ground, having a smaller whorl of leaves.

5. Less breakage in screening devices on harvesters.

6. Because of their round shape less losses due to the mechanical handling in receiving stations, wet hoppers, rock separation wheels, mechanical reloading and beet washers and elevators.

7. Because of shallower puller point operation, less clods are lifted than with standard type roots.

8. With spiked wheel operations, such as the Marbeet "Midget" used in this test, the beets come straight off of the periphery of the wheel making for uniform flat topping. Conventional beets too often grow in a "peaked" crown shape that goes up the wheel in an oblique direction.

# Sugar Beet By-products

# Studies of Beet-Top Silage Production in the Irrigated Rotation Experiments at the Scottsbluff, Nebraska, Field Station, 1942-1947

LIONEL HARRIS[1]

CROP ROTATION experiments under irrigation have been in operation since 1912 at the Scottsbluff Field Station in western Nebraska. The elevation of the Station is approximately 4,000 feet. The 37-year mean frost-free growing season extends from May 14 to September 27, or a period of about 136 days. Mean annual precipitation has been 13.64 inches. Of this amount 11.04 inches has fallen during the growing season, April to September, inclusive, mostly during April, May, and June. The soil at the Station is classed as Tripp very fine sandy loam.

During the 30-year period, 1912-41, the rotation experiments dealt mainly with studies of farm manure and legume crops (alfalfa and sweetclover) for the maintenance of soil productivity. In 1942, in addition to farm manure, studies of commercial fertilizers (phosphorus and nitrogen) were included in both legume and non-legume rotations. The crops grown in these rotations comprise sugar beets, potatoes, beans, barley, corn, alfalfa, and sweetclover.

This report deals only with the sugar beet crop, and mainly with the yields of sugar beet tops harvested for silage during the 6-year period 1942-47. Yields of sugar beets and gross sugar[2] have been tabulated to show the relationship between yields of tops, roots, and sugar.

Since 1942 sugar beet tops from most of the irrigated rotation sugar beet plots have been harvested from 1 to 10 days after the beets were topped with the exception of 1947 when snow delayed the harvest of tops for approximately 30 days. During the first 3 years (1942-44) the tops were stacked, and during the last 3 (1945-47) they were put in a pit silo. They were not chopped or cut before stacking or ensiling. Very good silage resulted from both methods of handling the tops. However, of the total weight of green tops ensiled, 78.0 percent was removed as edible silage in 1945 and 1946 from the pit silo, compared with 62.8 percent in 1942, 1943, and 1944 from the stacked tops. Edible silage referred to here represents that actually consumed by lambs in feeding experiments where soil and other inedible products were weighed back at intervals during the tests.

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[2]The author is indebted to S. B. Nuckols, Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, for sugar analyses and gross yields of sugar per acre.

In the stacked silage some mold grew on all the surface exposed to the air. Only part of this moldy silage was readily eaten by the lambs. Desirable tops of light-brown or green color were not encountered on the outside of the stack. Most of the outside tops to a depth of 6 to 12 inches were moldy, or dark-brown or black in color. In the pit silo very little surface was exposed to the air and a very small amount of moldy, slushy, or severely burned tops was encountered. Inside the stack the quality of the silage was as good as that produced in the pit silo.

The following discussion reports the yields of edible beet-top silage from various kinds of crop rotations: (a) untreated non-legume rotations, (b) untreated legume (alfalfa or sweetclover) rotations, (c) non-legume rotations treated with manure or commercial fertilizer, (d) legume (alfalfa) rotations treated with manure or commercial fertilizer, and (e) legume (sweetclover) rotations treated with manure or commercial fertilizer.

Yields of edible beet-top silage have been determined on the basis of silage production in a pit silo, and represent 78.0 percent of the green weight of tops harvested annually from each rotation.

## Discussion of Results

*Yields from Untreated Non-legume Rotations.*—This class of rotations includes No. 20, a 2-year rotation of beets and potatoes, and No. 35, a 3-year rotation of beets, barley, and potatoes. Neither rotation has received manure, commercial fertilizer, or other treatments during the past 36 years.

During the past 6 years the mean yield (3-year mean for rotation 20) of edible beet-top silage from these two rotations amounted to 2.14 tons per acre, or 702 pounds per ton of beets (table 1). The green tops at harvest contained 64.9 percent moisture. The beets contained 18.1 percent sugar, and yielded 2235 pounds of gross sugar per acre.

**Table 1.**—Yields of edible beet-top silage, sugar beets, and gross sugar in untreated non-legume rotations, 1942-1947, Scottsbluff Field Station.

| Rotation | Tons per acre | | Pounds silage per ton of beets | Percent | | Gross sugar per acre (pounds) |
|---|---|---|---|---|---|---|
| | Edible silage | Sugar beets | | Moisture in tops at harvest | Sugar in beets | |
| Rotation 20 ------ | 2.03[1] | 5.8 | 700 | 66.1[1] | 17.9 | 2087 |
| Rotation 35 ------ | 2.25 | 6.4 | 703 | 63.7 | 18.4 | 2383 |
| Mean ---------- | 2.14 | 6.1 | 702 | 64.9 | 18.1 | 2235 |

[1]Figures marked with (1) are 3-year means.

Crop Sequence

Rotation 20—Beets, potatoes.
Rotation 35—Beets, barley, potatoes.

*Yields from Untreated Legume Rotations.*—This group of rotations includes No. 33, a 3-year rotation of beets, barley planted with sweetclover, and potatoes; No. 49, a 4-year rotation of beets, barley planted with sweetclover, sweetclover pastured, and potatoes; No. 41, a 4-year rotation of beets, barley planted with alfalfa, alfalfa, and potatoes; and No. 63, a

6-year rotation of beets, barley planted with alfalfa, alfalfa 3 years, and potatoes. In rotations 33, 41, and 63, the legume is used as a green-manure crop for potatoes, and in rotation 49, as a pasture crop for sheep. The sugar beet crop follows potatoes in each of these rotations.

Yields of edible beet-top silage, sugar beets, and gross sugar are shown in table 2. The lowest yield of edible beet-top silage was 4.24 tons (4-year mean) produced in rotation 33, and the highest yield, 6.15 tons, in rotation 63. Yields in rotation 49 (5.66 tons) and 41 (5.99 tons) varied little from the yield in rotation 63. The mean yield of 5.51 tons from the four rotations (table 2) was 3.37 tons higher than the yield from the two untreated non-legume rotations (table 1). The 6-year mean yields (1942-47) of sugar beets were 13.9 tons in rotation 41, 11.6 tons in rotation 33, 11.0 tons in rotation 49, and 10.8 tons in rotation 63. The sugar content of the beets varied from 15.6 percent in rotations 49 and 63 to 16.6 percent in rotation 33. Moisture in the tops at harvest for the four rotations was 71.4 percent.

**Table 2.—Yields of edible beet-top silage, sugar beets, and gross sugar in untreated legume rotations, 1942-1947, Scottsbluff Field Station.**

| Rotation | Tons per acre | | Pounds silage per ton of beets | Percent | | Gross sugar per acre (pounds) |
|---|---|---|---|---|---|---|
| | Edible silage | Sugar beets | | Moisture in tops at harvest | Sugar in beets | |
| Rotation 33 | 4.24[1] | 11.6 | 731 | 70.7[1] | 16.6 | 3847 |
| Rotation 49 | 5.66 | 11.0 | 1029 | 68.9 | 15.6 | 3461 |
| Rotation 41 | 5.99 | 13.9 | 862 | 73.3 | 16.2 | 4498 |
| Rotation 63 | 6.15 | 10.8 | 1139 | 72.6 | 15.6 | 3328 |
| Mean | 5.51 | 11.8 | 940 | 71.4 | 16.0 | 3783 |

[1]Figures marked with (1) are 4-year means.

**Crop Sequence**

Rotation 33—Beets, barley-sweetclover, potatoes.
Rotation 49—Beets, barley-sweetclover, sweetclover pastured, potatoes.
Rotation 41—Beets, barley-alfalfa, alfalfa, potatoes.
Rotation 63—Beets, barley-alfalfa, alfalfa, alfalfa, alfalfa, potatoes.

*Comparison of Farm Manure and Commercial Fertilizer in Non-legume Rotations.*—This group comprises four pairs of rotations varying in length from 2 to 6 years. One member of each pair receives manure and the other, commercial fertilizer. For example, rotations 21 and 20C are alike in sequence but rotation 21 is treated with farm manure, and 20C with commercial fertilizer. Rotations 35B and 35C, 43B and 43C, and 67B and 67C are paired in a similar manner. The manure has been applied at the rate of 12 tons per acre annually to the sugar beet crops in rotations 21, 35B, 43B, and 67B. The sugar beet and potato crops in rotations 20C, 35C and 43C have each received annual applications of a fertilizer containing 56 pounds $P_2O_5$ and 51 pounds N since 1945. The two beet crops and the potato crop in rotation 67C have each received annual applications of a fertilizer containing 56 pounds $P_2O_5$ and 68 pounds N; the two barley crops have each received 68 pounds N, and the bean crop 56 pounds $P_2O_5$ since 1945. From 1942 to 1944, inclusive,

the applications of $P_2O_5$ were the same as listed above, but the nitrogen applied in each instance amounted to 26 pounds. Crop sequences, treatments, and yields are shown in table 3.

**Table 3.—A comparison of yields of edible beet-top silage, sugar beets, and gross sugar in non-legume rotations treated with farm manure or commercial fertilizer, 1942-1947, Scottsbluff Field Station.**

| Rotation | Tons per acre | | Pounds silage per ton of beets | Percent | | Gross sugar per acre (pounds) |
|---|---|---|---|---|---|---|
| | Edible silage | Sugar beets | | Moisture in tops at harvest | Sugar in beets | |
| (a) Manure: | | | | | | |
| Rotation 21 ------ | 5.09[1] | 15.2 | 670 | 69.5[1] | 17.8 | 5411 |
| Rotation 35B ---- | 5.76 | 14.9 | 773 | 71.8 | 17.4 | 5175 |
| Rotation 43B ---- | 4.18 | 12.7 | 658 | 69.4 | 18.3 | 4707 |
| Rotation 67B ---- | 6.46 | 14.3 | 903 | 72.6 | 16.7 | 4787 |
| Mean (a) -------- | 5.37 | 14.3 | 751 | 70.8 | 17.5 | 5020 |
| (b) Commercial Fertilizer: | | | | | | |
| Rotation 20C ---- | 5.14 | 16.0 | 642 | 68.5 | 17.8 | 5740 |
| Rotation 35C ---- | 4.44[2] | 14.5 | 612 | 74.3[2] | 17.2 | 4964 |
| Rotation 43C ---- | 3.62 | 12.4 | 584 | 66.5 | 17.9 | 4428 |
| Rotation 67C ---- | 6.69 | 15.4 | 869 | 71.8 | 16.9 | 5186 |
| Mean (b) -------- | 4.97 | 14.6 | 677 | 70.3 | 17.4 | 5079 |

[1]Figures marked with (1) are 4-year means.
[2]Figures marked with (2) are 3-year means.

**Crop Sequence and Treatments**

(a) Manure:
Rotation 21—Beets (M-12 tons), potatoes.
Rotation 35B—Beets (M-12 tons), barley, potatoes.
Rotation 43B—Beets (M-12 tons), barley, beans, potatoes.
Rotation 67B—Beets (M-12 tons), barley, potatoes, beets (M-12 tons), barley, beans.
(b) Commercial Fertilizer:
Rotation 20C—Beets (56 pounds $P_2O_5$ + 51 pounds N), potatoes (56 pounds $P_2O_5$ + 51 pounds N).
Rotation 35C—Beets (56 pounds $P_2O_5$ + 51 pounds N), barley, potatoes (56 pounds $P_2O_5$ + 51 pounds N).
Rotation 43C—Beets (56 pounds $P_2O_5$ + 51 pounds N), barley, beans, potatoes (56 pounds $P_2O_5$ + 51 pounds N).
Rotation 67C—Beets (56 pounds $P_2O_5$ + 68 pounds N), barley (68 pounds N), potatoes (56 pounds $P_2O_5$ + 68 pounds N), beets (56 pounds $P_2O_5$ + 68 pounds N), barley (68 pounds N), beans (56 pounds $P_2O_5$).

The mean yield of edible beet-top silage from the four manured rotations was 5.37 tons per acre compared with 4.97 tons from the four rotations treated with commercial fertilizer. The moisture content of the beet tops at harvest was 70.8 percent in the manured and 70.3 percent in the commercial-fertilized rotations. Sugar beet roots yielded 14.3 tons, contained 17.5 percent sugar, and produced 5,020 pounds of gross sugar per acre in the manured rotations, compared with 14.6 tons, 17.4 percent sugar, and 5,079 pounds of gross sugar in rotations treated with commercial fertilizer. Acre yields of beet-top silage were slightly below the yield produced by the untreated legume rotations (table 2), but much above the yield obtained in the untreated non-legume rotations (table 1).

*Comparison of Manure and Commercial Fertilizer in Legume (Alfalfa) Rotations.*—This group comprises one pair of 4-year rotations, and two pairs of 6-year rotations. One member of each pair receives farm manure and the other commercial fertilizer. Rotation 41B is a 4-year rotation of beets, barley planted with alfalfa, alfalfa, and potatoes. Rotation 63B is the same except that alfalfa is grown 3 years instead of 1 year. Rotation 66B is the same as 63B except that beans replace 1 year of alfalfa. The sugar beet crop in each of these rotations has received

farm manure at the rate of 12 tons per acre, annually. Rotations 41C, 63C, and 66C are respectively the same as those listed above except that the beet crop in each rotation has received a fertilizer containing 56 pounds $P_2O_5$ and 102 pounds N, and the potato crop, a fertilizer containing 56 pounds $P_2O_5$ since 1945. Previous to 1945, the applications of nitrogen amounted to 26 pounds per acre. Crop sequences, treatments, and yields are shown in table 4.

**Table 4.—A comparison of yields of edible beet-top silage, sugar beets, and gross sugar in legume (alfalfa) rotations treated with manure or commercial fertilizer, 1942-1947, Scottsbluff Field Station.**

| Rotation | Tons per acre | | Pounds silage per ton of beets | Percent | | Gross sugar per acre (pounds) |
|---|---|---|---|---|---|---|
| | Edible silage | Sugar beets | | Moisture in tops at harvest | Sugar in beets | |
| (a) Manure: | | | | | | |
| Rotation 41B ---- | 7.31 | 17.5 | 835 | 73.2 | 15.8 | 5550 |
| Rotation 63B ---- | 8.39 | 15.4 | 1090 | 76.9 | 14.4 | 4410 |
| Rotation 66B ---- | 9.58 | 16.7 | 1147 | 77.6 | 14.3 | 4764 |
| Mean (a) -------- | 8.43 | 16.5 | 1024 | 75.9 | 14.8 | 4908 |
| (b) Commercial Fertilizer: | | | | | | |
| Rotation 41C ---- | 8.00 | 17.2[1] | 930 | 73.9 | 16.7[1] | 5748[1] |
| Rotation 63C ---- | 7.50[1] | 14.9 | 1007 | 77.2[1] | 15.0 | 4476 |
| Rotation 66C ---- | 6.64 | 13.8 | 962 | 71.2 | 15.2 | 4231 |
| Mean (b) -------- | 7.38 | 15.3 | 966 | 74.1 | 15.6 | 4818 |

[1]Figures marked with (1) are 5-year means.

**Crop Sequence and Treatments**

(a) Manure:
Rotation 41B—Beets (M-12 tons), barley-alfalfa, alfalfa, potatoes.
Rotation 63B—Beets (M-12 tons), barley-alfalfa, alfalfa, alfalfa, alfalfa, potatoes.
Rotation 66B—Beets (M-12 tons), barley-alfalfa, alfalfa, alfalfa, potatoes, beans.
(b) Commercial Fertilizer:
Rotation 41C—Beets (56 pounds $P_2O_5$ + 102 pounds N), barley-alfalfa, alfalfa, potatoes (56 pounds $P_2O_5$).
Rotation 63C—Beets (56 pounds $P_2O_5$ + 102 pounds N), barley-alfalfa, alfalfa, alfalfa, alfalfa, potatoes (56 pounds $P_2O_5$).
Rotation 66C—Beets (56 pounds $P_2O_5$ + 102 pounds N), barley-alfalfa, alfalfa, alfalfa, potatoes (56 pounds $P_2O_5$), beans.

The mean yield of edible beet-top silage in the three legume rotations treated with farm manure was 8.43 tons per acre, compared with 7.38 tons in the legume rotations treated with commercial fertilizer. The manured, legume rotations produced 16.5 tons of beets per acre, with a sugar content of 14.8 percent, a yield of 4,908 pounds of gross sugar per acre, compared with 15.3 tons of beets with a sugar content of 15.6 percent and a yield of 4,818 pounds of gross sugar per acre in similar rotations treated with commercial fertilizer. Edible silage per ton of beets amounted to 1,024 pounds in the manured rotations and 966 pounds in those treated with commercial fertilizer.

As compared with the non-legume rotations (table 3), the rotations including alfalfa as a legume and treated with farm manure or commercial fertilizer produced higher yields of edible beet-top silage and higher yields of sugar beet roots, but lower percentages of sugar in the beets, and, consequently, slightly lower yields of gross sugar per acre. Moisture in the sugar beet tops at harvest amounted to 75.9 percent in the manured and 74.1 percent in the commercial fertilized legume rotations (table 4) compared with approximately 70 percent moisture in tops from similarly treated rotations without the legume crop (table 3).

*Yields Under the Influence of Manure and Commercial Fertilizer in Sweetclover Rotations.*—This group includes three 4-year rotations and one 3-year rotation. Rotation 49C is a rotation of barley planted with sweetclover, sweetclover pastured with sheep, potatoes, and sugar beets. Rotation 49D is the same as 49C except that the sweetclover crop the second year is used for hay and green manure instead of for pasture. Rotation 46B is a rotation of barley planted with sweetclover, sweetclover pastured, and two sugar beet crops. Number 33B is a rotation of beets, barley planted with sweetclover, and potatoes. Each sugar beet crop in rotations 49C and 49D has received a fertilizer containing 56 pounds $P_2O_5$ and 102 pounds N, and each potato crop, one containing 56 pounds of $P_2O_5$ annually since 1945. From 1942 to 1945, the application of N amounted to 26 pounds per acre in each instance. The second-year beet crop in rotation 46B and the beet crop in rotation 33B have received farm manure annually at the rate of 12 tons per acre since 1942. The manured and commercial-fertilized rotations in this group are not comparable on the basis of length of rotation and crop sequence. The data have been tabulated (table 5) on the basis of treatment to show the value of farm manure or commercial fertilizer in various unrelated rotations where sweetclover has been used as a green-manure or pasture crop.

The mean yield of edible beet-top silage from rotations 49C and 49D, treated with commercial fertilizer, amounted to 7.24 tons compared with 5.86 tons and 6.11 tons for the first and second-year beet crops, respectively, in rotation 46B, and 6.49 tons in rotation 33B. Yields of sugar beets were higher in the rotations treated with commercial fertilizer but the sugar content in the beets was lower, consequently the total yields of gross sugar was lower than the manured plots.

**Table 5.**—Yield of edible beet silage, sugar beets, and gross sugar in legume (sweetclover) rotations treated with farm manure or commercial fertilizer, 1942-1947, Scottsbluff Field Station.

| Rotation | Tons per acre | | Pounds silage per ton of beets | Percent | | Gross sugar per acre (pounds) |
|---|---|---|---|---|---|---|
| | Edible silage | Sugar beets | | Moisture in tops at harvest | Sugar in beets | |
| (a) Manure: | | | | | | |
| 46B—1st year | 5.86 | 12.5 | 938 | 72.2 | 16.5 | 4144 |
| 46B—2nd year | 6.11 | 13.7 | 892 | 70.2 | 16.8 | 4623 |
| 33B | 6.49[2] | 14.0 | 927 | 71.2 | 16.4 | 4614 |
| Mean (a) | 6.15 | 13.4 | 919 | 71.2 | 16.6 | 4460 |
| (b) Commercial Fertilizer: | | | | | | |
| Rotation 49C | 7.57[1] | 14.8 | 1023 | 76.7[1] | 14.4 | 4271 |
| Rotation 49D | 6.91[1] | 14.4 | 960 | 75.7 | 15.1 | 4355 |
| Mean (b) | 7.24 | 14.6 | 991 | 76.2 | 14.8 | 4313 |

[1]Figures marked with (1) are 5-year means.
[2]Figures marked with (2) are 3-year means.

**Crop Sequence and Treatments**

(a) Manure:
Rotation 46B—Barley-sweetclover, sweetclover pastured, beets, beets (12 tons M).
Rotation 33B—Beets (M-12 tons), barley-sweetclover, potatoes.
(b) Commercial Fertilizer:
Rotation 49C—Barley-sweetclover, sweetclover pastured, potatoes (56 pounds $P_2O_5$), beets (56 pounds $P_2O_5$ + 102 pounds N).
Rotation 49D—Barley-sweetclover, sweetclover hay and green manure, potatoes (56 pounds $P_2O_5$), beets (56 pounds $P_2O_5$ + 102 pounds N).

Table 6.—Summary of mean yields of edible beet-top silage, sugar beets and gross sugar in different types of rotations at the Stottsbluff Field Station, 1942-1947.

| Number of rotations | Type of Rotations | Tons per acre | | Pounds edible silage per ton of beets | Percent | | Gross sugar per acre (pounds) |
|---|---|---|---|---|---|---|---|
| | | Edible silage | Sugar beets | | Moisture in tops at harvest | Sugar in beets | |
| 2 | Untreated non-legume rotations | 2.14 | 6.1 | 702 | 64.9 | 18.1 | 2235 |
| 4 | Untreated legume rotations | 5.51 | 11.8 | 940 | 71.4 | 16.0 | 3783 |
| 4 | Manure in non-legume rotations | 5.37 | 14.3 | 751 | 70.8 | 17.5 | 5020 |
| 4 | PN in non-legume rotations | 4.97 | 14.6 | 677 | 70.3 | 17.4 | 5079 |
| 3 | Manure in legume (alfalfa) rotations | 8.43 | 16.5 | 1024 | 75.9 | 14.8 | 4908 |
| 3 | PN in legume (alfalfa) rotations | 7.38 | 15.3 | 966 | 74.1 | 15.6 | 4818 |
| 2 | Manure in legume (sweetclover) rotations | 6.15 | 13.4 | 919 | 71.2 | 16.6 | 4460 |
| 2 | PN in legume (sweetclover) rotations | 7.24 | 14.6 | 991 | 76.2 | 14.8 | 4313 |

**Summary**

During the 6-year period 1942-47, sugar beet tops from most beet plots in the irrigated rotation experiments at the Scottsbluff Field Station in western Nebraska have been harvested for silage production. During 3 years (1942-44) the tops were stacked on the ground, and during 3 years (1945-47) they were placed in a pit silo. The beet-top silage was used in lamb-feeding experiments where soil and other inedible products were weighed back at intervals during the tests. Consequently, edible silage in this discussion represents that actually consumed by lambs.

Of the total weight of green tops stacked (1942-44), 62.8 percent was edible silage, compared with 78.0 percent edible silage from tops placed in the pit silo in 1945 and 1946.

Yields of edible beet-top silage in this discussion have been determined on the basis of silage production in a pit silo, and represent 78.0 percent of the green weight of tops harvested annually from each rotation.

Yields of edible beet-top silage, sugar beets, and gross sugar per acre have been reported for each rotation with mean yields for different types of rotations grouped according to treatment. Farm manure has been applied to the sugar beet crop in the manured rotations at the rate of 12 tons per acre annually. Commercial fertilizer (treble-superphosphate and ammonium sulphate) has been applied in most instances at the rate of 112 pounds of $P_2O_5$ and 102 pounds of N per rotation.

The results according to rotation type and treatment are shown in table 6. Yields of edible beet-top silage ranged from 2.14 tons per acre in the untreated non-legume rotations to 8.43 tons in the legume rotations with alfalfa and treated with farm manure. Legume (alfalfa) rotations treated with commercial fertilizer produced 7.38 tons of edible silage per acre. A yield close to this (7.24 tons) came from legume (sweetclover) rotations treated with commercial fertilizer. Untreated legume rotations produced 5.51 tons, and manure or commercial fertilizer in non-legume rotations produced 5.37 and 4.97 tons of edible silage, respectively.

The highest yields of edible beet-top silage, and sugar beets occurred in legume (alfalfa) rotations treated with manure or commercial fertilizer, but because of higher sugar content, slightly higher yields of gross sugar per acre came from the non-legume rotations treated with manure or commercial fertilizer. Moisture in the sugar beet tops at harvest was higher in the legume rotations, than in those without a legume. Yields of edible beet-top silage in the legume rotations was very close to one-half the yield of sugar beet roots.

# Dehydrated Sugar Beet Leaves as a Feedstuff[1]

H. S. Wilgus,[2] H. P. H. Johnson,[3] A. L. Esplin,[4] and P. B. Smith[5]

Concomitant with the development and use of successful mechanical sugar beet harvesters there is a growing interest in the more efficient use of beet tops. The sugar beet industry needs more adequate information as to the most economical and effective means of utilizing this valuable by-product under various conditions. A number of workers in this country and abroad have demonstrated adequately the value of sugar beet tops as a feedstuff for ruminants. But a survey by the Beet Sugar Development Foundation (1),[6] covering 67 percent of the sugar beet acreage in 1946, shows that approximately 48 percent of the tops were left in the field for plowing under or for pasturing, approximately 46 percent were windrowed or stacked, presumably for feeding, 5 percent were fed green, and 1 percent were siloed.

It is probable that tops left in the field lose considerable nutritive value, especially carotene and to a lesser extent protein, before pasturing or feeding (2). Furthermore, much of the leafy portion, which makes up approximately 60 percent of the dried weight of the tops, is lost by shattering or trampling (3). The leaves contain most of the protein and vitamin content.

Ensiling will preserve much of the original value (2,3,4). Artificial dehydration should preserve most of the original value and provide a form of product which is easy to handle and to store. Some interest has been shown by alfalfa processors and by commercial feed manufacturers in dehydrated sugar beet leaves. Manufacturers of sugar beet harvesting machinery are vitally interested in knowing what uses will be made of tops and whether leaves will be harvested separately, since this affects the development of topping attachments on the harvester.

With these problems in mind, the Colorado Agricultural Experiment Station has initiated a project with the support of the Beet Sugar Development Foundation which has the following objectives:

1. The study the factors involved in the harvesting and dehydration of sugar beet leaves. This will include studies of the types of machinery required, comparison of products with and without the crowns, proper time of removal of leaves and effects on yield and sugar content of roots, methods and costs of dehydration, and removal of soil contamination.

2. To study the values and uses of the product, including variability of products from different areas. This phase will include determinations

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[6]The numbers in parentheses refer to literature cited.

of chemical and nutritional composition, feeding value, loss of plant nutrients from the soil, and economic evaluation of the product.

3. To compare the dehydration of beet leaves from an economic standpoint with other practices of beet-top utilization, such as pasturing of beet tops, feeding of beet-top silage, and feeding of dried beet tops, with the purpose of conserving the high nutrient values in commercial application and of conserving the soil.

This paper is a preliminary report of the initial progress on this project. Because artificial dehydration appeared to be the most effective means of preserving nutritive value of beet tops, the initial approach to this project was planned to ascertain if the yields per acre, nutrient analyses, and results of feeding trials would justify a more complete investigation.

## Procedures and Results

*Yields per Acre.*—Data were obtained from two fertilizer experiments to ascertain the effect of levels of fertility on yield and composition of tops. Experiment 3A consists of the same plots reported in these Proceedings by Whitney (5) utilizing land leveled into the subsoil. The plot treatments were set up with five replicates in the Latin-square design. This permitted statistical analysis of results to ascertain the least significant differences at the 5 percent and 1 percent levels. The tops from 20 beets were taken off each replicate. The leaves were immediately separated from the crowns by severing the stems about 2 inches above the crown in order to similate the action of a mower cuttingbar. Some low-lying leaves were thus left with the crown. Fresh weights of leaves and crowns were obtained separately. The samples were placed in an insulated box with dry ice. They were then removed to a freezing room. Each sample was reduced by careful sampling to one-half size, was finely ground in a food chopper, was remixed thoroughly, and was sampled for carotene assays immediately while frozen. A large aliquot was stored at 2 degrees centigrade for moisture and proximate analysis. Yields per acre were calculated by using an average population or stand count.

Experiment W47 consisted of a carefully selected field on which the various fertilizer applications were made on long strips of approximately 2 acres each. Two samples of tops from 20 beets were taken in the center of each plot, locations being one-third and two-thirds the distance from one end. Weighing and handling of each sample were the same as in experiment 3A.

The treatments and yields in experiment 3A are presented in table 1. The data for tops is that for leaves and crowns combined in the original proportions. Since the land had been leveled to the subsoil, the yields on the control plots were low. Phosphate alone did not improve yields. Nitrogen addition resulted in highly significant increases. The further addition of potash had no effect. The residual effect of manure was sufficient to pro-

vide significant increases in yields but not as great as in the case of the nitrogen application. There was a tendency for more succulent or moist growth on the plots receiving manure and nitrogen, the latter being accentuated by potash addition. There were no significant differences in the proportion of leaves to total tops but the proportion of tops to roots was increased by nitrogen applications. Harvest data by Whitney (5) showed yields of tops on these same plots about half of those reported here. This discrepancy might be explained in part by the fact that Whitney's data were based on salvage of tops following mechanical harvesting of the roots.

Table 2 shows the treatment and results obtained in experiment W47. Increments in nitrogen fertilization showed increments in top yields. Again, the dry-matter percentage in the tops decreased with increasing nitrogen application. Additional phosphate showed no effects on top yields. The proportion of leaves to tops and tops to roots increased as nitrogen additions were increased.

It is obvious that the yields of leaves and of total tops, expressed on the green or on the dry-matter basis, were sufficiently great as to yield important quantities of material when adequate nitrogen is present in the soil.

In removing leaves or tops for processing, it would be advantageous at times for the processor to remove them sometime previous to the harvesting of the roots. Therefore, the effects of removing the leaves 2 inches above the crown and of topping the beets on the sugar content of the roots at definite intervals following such removals were made. The results of two such studies, one starting September 18, 1947, and the other starting October 9, 1947, are graphically presented in figure 1. It is obvious that roots must be harvested within 24 hours after leaves or tops are removed, if a decline in sugar content in the roots is to be avoided.

FIGURE 1

EFFECT OF REMOVAL OF LEAVES & TOPS ON SUGAR CONTENT OF ROOTS

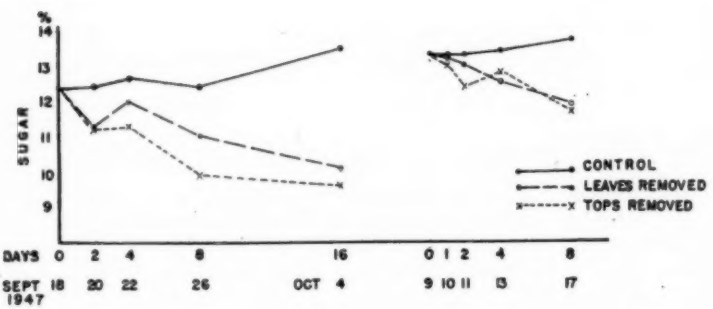

Table 1.—Experiment 3A—Effects of fertilizer treatments on yields of leaves and tops.

| Treatment[1] per acre basis | Leaves | | | Tops | | | Leaves/Tops | Tops/Roots |
|---|---|---|---|---|---|---|---|---|
| | Fresh | Dry | Dry Matter | Fresh | Dry | Dry Matter | | |
| | Tons | Tons | Percent | Tons | Tons | Percent | Percent | Percent |
| 1. None | 8.2 | 1.0 | 14.4 | 12.2 | 1.6 | 15.2 | 64 | 149 |
| 2. Manure, 27 tons[2] | 13.6 | 1.7 | 13.0 | 20.6 | 2.8 | 13.9 | 62 | 124 |
| 3. TSP, 300 | 7.4 | 1.0 | 15.3 | 11.6 | 1.8 | 16.7 | 58 | 96 |
| 4. TSP, 300; AN, 262 | 23.2 | 2.8 | 11.9 | 34.7 | 4.3 | 12.4 | 65 | 186 |
| 5. TSP, 300, AN 262; KS, 523 | 23.8 | 2.5 | 10.7 | 34.9 | 4.1 | 11.9 | 61 | 178 |
| L.S.D. at 5 percent | 2.5 | 0.3 | 1.8 | 2.8 | 0.4 | 1.9 | | |
| L.S.D. at 1 percent | 3.4 | 0.5 | 2.5 | 3.8 | 0.5 | 2.6 | | |

[1]TSP, treble superphosphate; AN, ammonium nitrate; KS, potassium sulfate, in pounds.
[2]Applied the previous crop year.

Table 2.—Experiment W47—Effects of fertilizer treatments on yields of leaves and tops.

| | Treatment[1] | | Leaves | | | Tops | | | Leaves/Tops | Tops/Roots |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11-46-0 | AN | Fresh | Dry | Dry Matter | Fresh | Dry | Dry Matter | | |
| | lbs./A | lbs./A | Tons | Tons | Percent | Tons | Tons | Percent | Percent | Percent |
| 1. | 65 | --- | 4.0 | 0.6 | 13.9 | 7.7 | 1.2 | 16.1 | 44 | 59 |
| 2. | 65 | 240 | 7.5 | 1.1 | 14.1 | 12.4 | 1.7 | 14.1 | 61 | 78 |
| 3. | 65 | 480 | 11.1 | 1.5 | 13.2 | 18.6 | 2.5 | 13.6 | 58 | 107 |
| 4. | 65 | 720 | 15.6 | 2.1 | 13.2 | 24.0 | 3.1 | 12.9 | 67 | 153 |
| 5. | 215 | 200 | 8.7 | 1.1 | 12.4 | 14.0 | 1.9 | 13.2 | 58 | 92 |
| 6. | 215 | 200 | 8.7 | 1.2 | 13.2 | 13.9 | 2.0 | 14.6 | 57 | 90 |
| plus TSP, 1250 | | | | | | | | | | |

[1]AN, ammonium nitrate; TSP, treble superphosphate.

*Composition of Tops.*—A. *Fertilizer trials.*—Proximate analyses for crude protein and ash were done on the samples from each plot in the usual manner. Soluble ash was obtained by treating the total ash with hot 10 percent hydrochloric acid and filtering. The residue was dried and weighed to obtain the insoluble ash. This represents very crudely the contamination with dirt, hence the soluble ash more nearly represents the true inherent ash content of samples.

Analyses for carotene were done by a modification of the method described by Charkey and Wilgus (6). Riboflavin assays were conducted according to the method of Roberts and Snell (7).

The results of analyses in experiment 3A are given in table 3. Crude protein contents of both leaves and tops were increased to a highly significant degree by nitrogen additions to the soil but not by the residual effect of manure or by additions of phosphate or potash. Soluble ash contents were unaffected by manure or potash, were increased significantly by phosphate alone, but were decreased significantly by the addition of nitrogen in addition to the phosphate. Carotene and riboflavin contents were so variable within samples and between samples as to render any differences in the average results of questionable significance.

The crude protein analyses of the leaves and tops in experiment W47, table 4, did not show any consistent trend, although those of the tops without nitrogen addition were somewhat lower. As in experiment 3A, the soluble ash was depressed by nitrogen additions to the soil and was increased by phosphate additions (lots 5 and 6). Again, there were wide and evidently independent variations in carotene content.

B. *Dehydrated samples.*—Samples of dehydrated sugar beet leaf meal were obtained from commercial alfalfa dehydrating plants. One processed in 1945 was from a Nebraska source. Another processed in 1946 was from a Minnesota processor. In both instances the material was chopped and then dehydrated in a commercial dehydrator commonly used for alfalfa.

In 1947, two loads each of fresh beet leaves and of fresh beet tops were dehydrated by a near-by alfalfa processor. The former were cut and chopped with a field chopper and dehydrated after about 8 hours accidental delay between harvesting and drying. Owing to the low temperature in the dehydrator, it was necessary to complete the drying of the material in a barn loft. The tops were of low quality and dirty. They were chopped in a hammermill equipped with a 4-inch square screen and no blower. The material was finely pulped, the result of reducing the crowns to the degree necessary for drying. Both products were abnormally brown. Complete analyses have not been completed but the crude protein content of the leaf meal was 12.2 percent and that of the top meal was 8.1 percent.

A comparison of the analyses of the 1945 and 1946 meals with the average analysis of other meals is given in table 5.

Table 3.—Experiment 3A—Effects of fertilizer treatments on composition of leaves and tops.

| Treatment[1] per acre basis | Leaves, dry-matter basis | | | | | Tops, dry-matter basis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Crude protein | Ash[2] | | Carotene | Riboflavin | Crude protein | Ash[2] | | Carotene | Riboflavin |
| | | Total | Soluble | | | | Total | Soluble | | |
| | percent | percent | percent | mg./kg. | mg./kg. | percent | percent | percent | mg./kg. | mg./kg. |
| 1. None | 15.7 | 17.7 | 15.4 | 262 | 14.6 | 14.0 | 19.9 | 14.6 | 196 | 12.5 |
| 2. Manure, 27 tons[3] | 15.9 | 16.0 | 14.7 | 233 | 13.0 | 13.8 | 17.6 | 14.4 | 176 | 11.6 |
| 3. TSP, 300 | 13.8 | 19.5 | 16.8 | 222 | 13.4 | 12.2 | 22.9 | 16.1 | 154 | 11.4 |
| 4. TSP, 300; AN, 262 | 19.5 | 13.7 | 13.2 | 314 | 14.9 | 17.8 | 15.5 | 13.6 | 231 | 13.0 |
| 5. TSP, 300; AN, 262; KS, 523 | 21.5 | 14.9 | 14.2 | 263 | 13.4 | 18.4 | 16.0 | 13.7 | 193 | 11.5 |
| L.S.D. at 5 percent | 2.7 | 2.2 | 1.4 | | | 2.0 | 2.8 | 1.2 | | |
| L.S.D. at 1 percent | 3.7 | 3.1 | 1.9 | | | 2.7 | 3.9 | 1.6 | | |

[1]TSP, treble superphosphate; AN, ammonium nitrate; KS, potassium sulfate, in pounds.
[2]Soluble ash based on solubility in hot 10 percent hydrochloric acid.
[3]Applied the previous crop year.

Table 4.—Experiment W47—Effects of fertilizer treatments on composition of leaves and tops.

| Treatment[1] | | Leaves, dry-matter basis | | | | Tops, dry-matter basis | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11-46-0 | AN | Crude protein | Ash[2] | | Carotene | Crude protein | Ash[2] | | Carotene |
| | | | Total | Soluble | | | Total | Soluble | |
| Pounds/A | Pounds/A | percent | percent | percent | mg./kg. | percent | percent | percent | mg./kg. |
| 1. 65 | --- | 14.6 | 18.9 | 18.4 | 293 | 12.7 | 19.6 | 17.5 | 198 |
| 2. 65 | 240 | 14.6 | 16.4 | 16.2 | 248 | 14.4 | 18.3 | 17.3 | 147 |
| 3. 65 | 480 | 16.2 | 16.1 | 15.9 | 202 | 16.6 | 18.1 | 16.6 | 136 |
| 4. 65 | 720 | 15.0 | 16.1 | 15.9 | 213 | 15.0 | 17.4 | 16.3 | 187 |
| 5. 215 | 200 | 17.0 | 20.2 | 19.8 | 273 | 16.4 | 21.4 | 19.7 | 209 |
| 6. 215 | 200 | 17.3 | 21.0 | 20.6 | 255 | 15.5 | 22.3 | 20.0 | 180 |
| plus TSP, 1250 | | | | | | | | | |

[1]AN, ammonium nitrate; TSP, treble superphosphate.
[2]Soluble ash based on solubility in hot 10 percent hydrochloric acid.

Some of the data on the 1945 sample from Nebraska was derived from the paper by Robertson, Brin, and Norris (8). This paper was a report on chick growth trials using material from this same production.

The crude protein analyses of the beet-leaf meals were lower than expected from the analysis of green material reported in tables 3 and 4. The commercial laboratories analyzing the 1945 and 1946 samples immediately after dehydration reported 21.3 percent and 22.2 percent crude protein, respectively. Analyses by the Cornell and Colorado Experiment Stations at a later date, however, were the ones reported in table 5. In the case of the 1947 sample, the green chopped leaves sampled at time of harvest showed 20.0 percent crude protein on a dry-matter basis. This is materially higher than the amount found in the dehydrated meal, namely, 12.2 percent. The lower figures obtained in the two Experiment Station laboratories on the 1945 and 1946 samples and the discrepancy between the crude protein at the time the 1947 sample was harvested and the time it was dried undoubtedly represent a loss of non-protein nitrogen. Guilbert, Miller, and Goss (3) reported figures from the literature indicating that true protein of beet tops runs from 58 to 74 percent of the crude protein.

The variations in carotene reported for the dehydrated products are not unusual. They reflect not only differences present in the raw material, but also the results of processing and of storage.

The data taken as a whole indicate that properly processed sugar beet leaf meal may be comparable to alfalfa leaf meal in general composition. It may run variably lower in crude protein, may contain about half as much fiber and twice as much ash, and about the same range of carotene content.

*Feeding Trials.*—A. *Chickens.*—Since a considerable portion of dehydrated green feed is incorporated in poultry rations in this country and since poultry are much more critical in their nutritional requirements than ruminants, trials comparing dehydrated beet leaves and tops with dehydrated alfalfa leaf meal were conducted with chickens. Because beet leaves are rich in oxalates (table 5) which are known to interfere with calcium metabolism, the trials were in part designed to ascertain the effects of this component in poultry rations. Details of these experiments will be published elsewhere. The pertinent observations are presented here.

The dehydrated beet leaf meal prepared in 1945 was compared with dehydrated alfalfa leaf meal at a 10-percent level in starting mashes. No differences in growth to 6 weeks of age were noted when the mashes contained 50 percent over the minimum level of calcium required by chicks. When the calcium level was reduced to the minimum requirement, the beet leaf meal caused reduced growth and calcification, presumably because the oxalate in the meal rendered some of the dietary calcium unavailable.

The beet leaf meal prepared in 1946 was similarly compared to dehydrated alfalfa leaf meal at the 5 percent level but with adequate calcium

in the ration. The growth of chicks to 5 weeks of age fed the ration containing beet leaf meal slightly exceeded the growth of those fed the ration containing alfalfa leaf meal.

In a third trial, the beet leaf meal prepared in 1947 was compared to dehydrated alfalfa leaf meal at levels of 5 and 10 percent and with the beet top meal prepared in 1947 at levels of 5, 10, and 15 percent. Growth was comparable at the 5 percent level of all three products but the beet leaf meal and the beet top meal produced increases in growth at the 10 percent levels, whereas the alfalfa leaf meal caused a marked decrease in growth.

A trial was conducted with laying pullets comparing 5 percent of dehydrated alfalfa meal with the same amount of the beet leaf meal prepared in 1946. An all-mash breeding ration was used. No differences in body weight, hatchability, early growth of offspring, egg weight, or calcium and phosphorus balances were noted. Fertility was lower on the beet product but this may have been due to the individual male in this pen. The beet leaf meal did cause slight abnormal discoloration of the yolks of eggs during prolonged storage.

B. *Lamb fattening.*—Two lots of 20 lambs each were fattened for 126 days in the winter of 1946-47. One pen received a ration of rolled barley, ground corn, chopped alfalfa, and salt. The other received 0.1 pound per head per day of beet by-product pellets in addition. These pellets were composed of the dehydrated beet leaf meal prepared in 1946, 20; soybean oil meal, 20; dried beet pulp, 34; beet molasses, 20; limestone, 4; steamed bone meal, 2. The results of this trial, shown in table 6, indicate that the pellets were highly acceptable and could be profitably utilized.

Preliminary results of another similar trial with lambs in 1947-48 season indicate that the dehydrated beet leaf meal and the dehydrated beet top meal prepared in 1947 were comparable to dehydrated alfalfa leaf meal in acceptability and results when hand-fed to lambs.

## Discussion

The yields per acre of leaves and tops observed on intermediate levels of nitrogen fertilizer additions in these studies approximated for the leaves about 8 tons fresh and 1 ton dry and for the whole tops about 14 tons fresh and 1.75 tons dry. The fresh top yield was approximately the same as that of the roots in weight. Skuderna and Sheets (9) quote an average yield of fresh tops at 30 to 70 percent that of the marketed weight of roots on irrigated land. Dunn and Rost (10) reported a yield of 75 percent in the Red River Valley. The figures in this paper show that the ratio depends on the level of nitrogen fertility. This is not in conformity with the results reported by Dunn and Rost (10). Some of the improvement in this ratio may be due to the fact that our samples were harvested by hand. Discrepancies in yields of tops noted in experiment 3A may be the result of hand-versus-machine harvesting.

Table 5.—Composition of dehydrated meals, dry-matter basis.

| Sample | Crude protein | Crude fat | Crude fiber | Total ash | Ca | P | Oxalate | Carotene | Ribo-flavin/lb. |
|---|---|---|---|---|---|---|---|---|---|
| | percent | percent | percent | percent | percent | percent | percent | mg./kg. | mg. |
| 1. 1944 Beet Leaf[1] | 18.8 | 2.3 | 11.9 | 18.0 | -- | -- | -- | 95 | 9 |
| 2. 1945 Beet Leaf (Nebraska)[2] | 14.4 | 2.7 | 10.3 | 18.0 | .67 | .28 | 4.5 | 128 | 13 |
| 3. 1946 Beet Leaf (Minnesota)[3] | 14.4 | 3.8 | 9.9 | 19.5 | .93 | .20 | 7.8 | 282 | -- |
| 4. Alfalfa Leaf[4] | 21 | 3.0 | 18.0 | 11.0 | 1.40 | .30 | 1.5 | 200 | 17 |
| 5. Alfalfa Hay[4] | 16.3 | 2.2 | 32.1 | 9.2 | 1.58 | .23 | -- | -- | -- |

[1]Data from Holly Sugar Corp.
[2]Data from commercial laboratory, Colorado and Cornell Experiment Stations.
[3]Data from commercial laboratory and Colorado Agricultural Experiment Station.
[4]Data adapted from Feeds and Feeding by Morrison.

Table 6.—Preliminary lamb fattening trial, 1946-1947.

| Lot | Average gain per day | Average feed cost | Cost per 100 pounds gain | Comments |
|---|---|---|---|---|
| | pounds | $ | $ | |
| 1. Control | .35 | 9.82 | 23.01 | No differences in carcass |
| 2. Beet Meal Pellets | .33 | 9.59 | 22.01 | yields, grade, or price. |

The proportion of leaves to entire tops (60 percent) in these data agree well with those reported by Skuderna et al. (9) and Guilbert and co-workers (3).

The data in the two fertilizer experiments demonstrate that the leaves and tops at time of harvest are rich in crude protein and carotene. The supply of these two nutrients is deficient for livestock needs in the more important beet-growing areas in the United States. Not only the yields per acre, but also the crude protein content can evidently be increased by assuring adequate nitrogen in the soil. The high ash content, which is a limiting factor in feeding beet tops and leaves, is evidently reduced by such nitrogen additions. On the other hand, the added nitrogen apparently produces a more succulent or moist top which would be a drawback in dehydrating or ensiling. The additional increase of moisture in the presence of additional potash in experiment 3A is in agreement with the observations of Dunn and Rost (10).

The data presented in this paper on the composition of the tops are in close agreement with those reported by Dunn and Rost (10) and by Guilbert et al. (3). Both of these groups of authors indicate that the feeding value of beet tops is equal to that of alfalfa hay on a dry-matter basis. The beet tops are slightly higher in crude protein and nitrogen-free extract. They contain only about one-third as much fiber but about twice as much ash.

The composition of the dry matter in green leaves found in this study is quite comparable to dehydrated alfalfa leaf meal except that the crude protein may be slightly lower, the fiber half as high, and the ash twice as high. The carotene contents appear to be very much in the same ranges. The riboflavin appears to be slightly lower. The evident loss of nitrogen on dehydration and possibly subsequent storage, an observation in agreement with that of Ingraham (11), warrants further investigation on the nature of the nitrogenous compounds in beet leaves and tops. The loss indicated in our observation is very close to the non-protein nitrogen percentages quoted by Guilbert et al. (3).

The successful use of dehydrated beet leaf meals in growing rations containing adequate calcium substantiates the report of Robertson, Brin, and Norris (8). It is possible that dehydrated beet leaf meal and beet top meal do not possess the growth-inhibiting property found in some alfalfa meals.

While beet leaf meal was used successfully in a chicken breeding ration, further trials are essential to ascertain the reliability of observations on discoloration of yolks of eggs during storage. Also the efficiency of utilization of carotene and other vitamins and the biological value of the protein must be determined.

The preliminary trials on the fattening of lambs indicate that the dehydrated beet products are acceptable to lambs. Their true place in lamb and cattle rations, especially as protein and carotene carriers similar to

dehydrated alfalfa, awaits evaluation. The high values for cattle and lambs of the fresh and pastured tops and of the ensiled tops have been demonstrated by Maynard (12) and Guilbert et al. (3). These reports indicate that beet tops and alfalfa hay are equivalent in feeding value on the dry-matter basis. Thus a 15-ton yield of sugar beets may yield about 15 tons of tops which on a dry-matter basis is equivalent to about 2.25 tons of alfalfa hay or 1.5 tons of barley.

The analytical data indicate that beet leaves and tops are of great potential value as sources of crude protein and carotene. The feeding trials show that the dehydrated products are highly acceptable to poultry and lambs. It appears obvious that these materials are so comparable to similar alfalfa products as to be competitive as a feed stuff. Further analytical and feeding data are essential to ascertain whether the beet products may not prove superior to those from alfalfa. Such studies will include methods of ensiling.

In competition with alfalfa as a source of material for dehydration, beet-top products have several disadvantages which must be overcome. The leaves contained about 87.5 percent moisture in these trials and the tops contained about 86 percent. This is in contrast to alfalfa which averages between 75 and 80 percent moisture. This means that to get a ton of dehydrated leaf meal, containing 10 percent of residual moisture, there must be dehydrated approximately 14,500 pounds of fresh beet leaves as compared to approximately 8,000 pounds of green alfalfa containing 77.5 percent moisture. This requires the evaporation of approximately 12,500 pounds of water in the case of the beet leaves as compared to approximately 6,200 pounds of water in the case of alfalfa. Thus, dehydration costs of beet leaves will be approximately twice that of alfalfa.

The higher moisture content of beet leaves and beet tops is also a problem in ensiling them. Material for ensilage should contain approximately 65 to 70 percent moisture in order to aid the preservation and to avoid heavy drainage losses.

Another problem in dehydrating beet-top products is the difficulty of finely chopping three types of wet materials, leaf, stem, and crown, which occur in the whole tops without finely macerating the green tissue and thereby hastening enzymatic destruction of carotene. Unless the crown particles are very finely divided they will cork over in the dehydrator and will not dry out inside.

Another problem is the need for developing mechanical means of harvesting and handling the tops or leaves with an absolute minimum of soil contamination. Still more serious is the problem of overcoming the labor and equipment load needed at harvest time in competition with the harvesting of the roots. This is caused by the fact that it is necessary to harvest the roots the same day, or not later than 24 hours after removing the tops or leaves, if loss of sugar in the roots is to be avoided. These and many other lesser problems are the subject of further intensive study in which progress is being made.

## Conclusions

Under favorable conditions the yield of sugar beet tops may equal or exceed the yield of roots on a fresh water basis. The leaves constitute about 60 percent the weight of the tops (leaves plus crowns). Yields of sugar beet leaves and tops can be improved by assuring adequate amounts of nitrogen in the soil.

Sugar beet leaves and tops possess nutritive values, especially in crude protein and carotene, quite similar to comparative alfalfa products on a dry-matter basis. Feeding trials with chicks, breeding hens, and fattening lambs indicate that dehydrated beet leaf meal is highly acceptable in comparison with alfalfa leaf meal.

The roots should be harvested within 24 hours following the removal of the tops or leaves in order to avoid significant loss of sugar. This creates a labor and machinery problem in handling the tops or leaves for immediate processing. The high moisture content of sugar beet leaves or tops at least doubles the dehydration cost in comparison with alfalfa and causes greater losses in ensiling.

The preliminary data obtained in this study are sufficiently encouraging to justify the intensive study in progress on these problems.

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# Tests on Loss Reduction in Sliced Beet Pulp

H. R. GUILBERT[1]

CALIFORNIA data show dry-matter losses of about 40 percent in wet pulp stored in open silos. R. D. Jones of the Spreckels Company found that 2.5 to 7.5 percent of molasses added to pulp in small pits reduced this loss from about 50 percent to 25 percent. The molasses-treated pulp was slightly higher in digestible nutrients and the enhanced feeding value was confirmed by lamb-fattening trials.

In laboratory fermentation tests, the addition of urea and of molasses tended to increase the proportions of volatile acid. Four percent of molasses inhibited acid formation.

Tests were made on preservation of pressed pulp in barrels. Addition of 1 percent molasses and 0.13 percent urea resulted in a sloppy product—40 to 50 percent liquid that would be lost by drainage. Addition of 10 to 14 percent rolled barley reduced moisture to about 80 percent, resulted in an excellent feed with little objectionable odor, and no drainage loss. If moldy material were removed from the top the total loss was 6.0 percent.

In cooperation with the Fontana Ranch Company a test was made with 100 tons of pressed pulp mixed with 10 tons of ground barley placed in a corner of their open reservoir. The settled mass was about 3 feet deep. Surface exposure was excessive and it was exposed to winter rain. The loss was over 50 percent but the remaining feed was excellent. This experience in contrast to the result from the covered barrels suggests that rain leached out acid and favored continued fermentation, liquefaction and drainage.

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# Feeding Values of Sugar Beet By-Products

E. J. MAYNARD[1]

THE PURPOSE of this discussion is to present a general summary of results secured in various carefully controlled feeding experiments with sugar beet by-products to demonstrate their approximate values in terms of corn and alfalfa hay.

In a previous report to the Society in 1944 on the Feed-Replacement Values of Sugar Beet By-Products.[2] I reported these replacement feed values in terms of corn or alfalfa hay by a conversion of the digestible nutrients in the feeds saved or replaced by these by-products.

As such a conversion has tended to be somewhat confusing to the layman, the study presented here has been based directly on the actual amounts of both grain and hay that were replaced.

The summary presented herein includes experimental data from livestock feeding tests conducted at six Western State and Federal Agricultural Experiment Stations where each beet by-product had been fed in a ration with grain and alfalfa hay and where its feed-replacement value had been determined on the basis of feed fed and gains in weight secured on fattening cattle or lambs in comparison with a check lot of comparable livestock fattened with a ration of grain and hay alone in the same experiment.

The summary includes 27 separate tests with field-cured beet tops that were hauled and fed in dry lot; 29 feeding tests with wet beet pulp; 42 tests with dried beet pulp and 6 tests with Steffens discard molasses.

No distinction was made between dried beet pulp and dried molasses beet pulp for the reason that feeding tests with cattle and lambs have shown no significant difference in the feed-replacement values of these two products when they have been used as a fattening feed with grain and alfalfa hay.

The field-cured dried tops were hauled from the field and fed through panels, in troughs or on straw bedding. Grain was hand-fed and alfalfa hay was self-fed in all tests.

The amounts of beet tops fed in these experiments were reported on the basis of tops produced per ton of harvested beets and were assumed to represent an average of 200 pounds of dry substance in tops and crowns per ton of beets harvested. The variation in the amounts of grain

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[1]General Livestock Consultant, The Great Western Sugar Company.
[2]American Society of Sugar Beet Technologists, Rept. 1944, page 144.

fed in the different tests produced a rather wide variation in the ratio between grain and alfalfa hay saved or replaced by the beet tops fed.

The feed-replacement value of the tops produced per ton of beets varied from 18 pounds of corn plus 243.5 pounds of alfalfa hay for an average of 6 tests conducted at the Belle Fourche station in South Dakota to 103.2 pounds of corn plus 80.4 pounds of alfalfa hay for an average of 7 tests conducted at substations of the Wyoming Experiment Station.

The weighted average feed-replacement value for the field-cured dried tops produced from a ton of beets and fed with grain and alfalfa hay in all of the 27 feeding tests considered was 46 pounds of corn plus 150 pounds of alfalfa hay.

A California Agricultural Experiment Station digestion trial with steers[3] has shown 63.9 pounds of total digestible nutrients in 100 pounds of dry substance in tops. An average of 6 California beet-top samples calculated on these same coefficients of digestibility showed 64.2 pounds of digestible nutrients per 100 pounds of dry matter in tops, while an average of 48 American and European beet-top samples showed 59.5 pounds of digestible nutrients.

On the basis of a 200-pound recovery of dry substance in the tops produced per ton of beets the corn and alfalfa hay replaced by 100 pounds of dry substance in the field-cured beet tops fed in these 27 tests amounted to 56.3 pounds of total digestible nutrients.

Sugar beet tops are a good livestock fattening feed as well as a growth-producing feed. Many cattle and sheep are successfully fattened on rations containing relatively large quantities of beet tops with little or even no grain included.

Beet tops are relatively high in digestible protein which gives them a narrow nutritive ratio very similar to that of alfalfa hay. But beet tops are much lower in fiber content than alfalfa hay and the fiber they do contain is more highly digestible than that in alfalfa hay.

While beet tops are often classed with or compared to alfalfa hay, the amount of grain as well as hay that they can replace apparently justifies their use as a grain substitute in livestock fattening rations.

Possibilities for the mechanical harvest and better conservation of beet tops will be provided with the present transition to mechanical harvesting of sugar beets. But some of these new beet-harvesting methods may result in greater losses to feed nutrients in beet tops than have been experienced in the past or may even cause a total loss of the beet-top crop as a livestock feed unless its true feeding value is more clearly recognized and protected.

[3]Utilization of Sugar Beet Tops, Calif. Exp. Sta. Rept., 1943. Guilbert, Regan & Miller.

As with beet tops there was a rather wide variation in the ratio between grain and alfalfa hay replaced by the wet beet pulp in the various tests studied.

The overall weighted average for the 29 separate feeding tests showed that a ton of wet beet pulp fed with grain and alfalfa hay replaced 148.6 pounds of corn plus 355.4 pounds of hay.

The digestible nutrients contained in the corn and alfalfa that was replaced by wet beet pulp are considerably in excess of those attributed to a ton of wet beet pulp. This finding, however, only serves to indicate additional beneficial effects provided by this feed.

Possibilities for more efficient conservation of both the dry substance and digestible nutrients in wet beet pulp through the addition of grain or molasses in the siloing process have been well demonstrated in tests conducted by the Spreckels Sugar Company[4] and the California Experiment Station.

One of the most effective methods for obtaining more efficient results from this feed in recent years has come through a recognition of the necessity to guard against a deficiency of phosphorus in rations where it is used in considerable quantity.

There was very little variation in the ratio between grain and alfalfa hay replaced by dried beet pulp.

The weighted average for the 42 feeding tests studied showed that a ton of dried beet pulp fed with grain and alfalfa hay replaced 1,782.2 pounds of corn plus 835.6 pounds of alfalfa hay. Many feeding experiments have conclusively demonstrated that dried beet pulp should always be fed mixed with grain or with corn fodder or silage or with some protein concentrate to realize its full replacement value. In such combinations it is fully equal to and often proves superior to grain, but, fed as a "lone" carbohydrate it generally returns only about ¾ of a grain value. Extensive studies with beet molasses have shown that when it is fed in limited amounts with grain and hay to cattle or lambs it has a high feed value.

The average for the 6 feeding tests reported showed that a ton of Steffens' process beet molasses replaced 1,136 pounds of corn plus 1,469 pounds of alfalfa hay.

The experiments reported in this summary were conducted over a wide area and under variable conditions but all tests were carried out under practical farm feeding conditions.

The results reported should approximate those that might be expected on any beet farm where reasonable care is used in the harvesting and conservation of the beet by-products and where these by-products are handled and fed with grain and alfalfa hay in an efficient manner.

[4]American Society of Sugar Beet Technologists Rept. 1946—J. E. Coke, R. D. Jones. Spreckels Sugar Co., page 117.

**Feed-Replacement Values of Sugar Beet By-products in Terms of Corn and Alfalfa Hay**
**Corn and Alfalfa Replaced by the By-Products from 1 Ton of Beets**

| | By-product | Corn pounds | Alfalfa hay pounds | Number of tests |
|---|---|---|---|---|
| Colorado Experiment Station | Tops | --- | 248.5 | 2 |
| | Wet pulp | 25.5 | 87.0 | 4 |
| | Dried pulp | 77.6 | 42.4 | 5 |
| Wyoming Experiment Station | Tops | 103.2 | 80.4 | 7 |
| | Wet pulp | 41.0 | 107.3 | 10 |
| | Dried pulp | 81.1 | 41.0 | 6 |
| Nebraska—U. S. Scottsbluff Experiment Station | Tops | 29.2 | 113.6 | 6 |
| | Wet pulp | 22.2 | 35.6 | 3 |
| | Dried pulp | 83.0 | 32.0 | 16 |
| Montana and U. S. Huntley Experiment Station | Tops | 29.3 | 167.6 | 8 |
| | Wet pulp | 52.2 | 113.1 | 12 |
| | Dried pulp | 77.7 | 40.6 | 15 |
| South Dakota—U. S. Belle Fourche Experiment Station | Tops | 18.0 | 243.5 | 6 |
| California Experiment Station | Tops | --- | 235.0 | 6 |
| Weighted average of grain and hay replaced by the by-products | Tops | 46.0 | 150.0 | 27 |
| | Wet pulp | 41.6 | 99.5 | 29 |
| | Dried pulp | 80.2 | 37.6 | 42 |

| | By-product | Corn pounds | Alfalfa hay pounds |
|---|---|---|---|
| Corn and alfalfa replaced by 1 ton of by-product | Tops (70 percent D.M.) | 322.0 | 1050.0 |
| | Wet pulp (11 percent D.M.) | 148.6 | 355.4 |
| | Dried pulp (90 percent D.M.) | 1782.2 | 835.6 |

Tops dry matter, 10 percent of beet tonnage or 200 pounds.
Wet pulp, 11 percent dry matter, 28 percent of beet tonnage or 560 pounds.
Dried pulp, 90 percent dry matter, 4½ percent of beet tonnage or 90 pounds.

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